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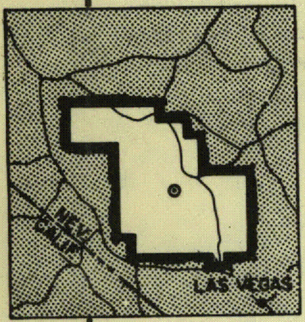
PRELIMINARY REPORT

OPERATION PLUMBBOB



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MAY-OCTOBER 1957

Project 32.3

EVALUATION OF COUNTERMEASURE SYSTEM COMPONENTS AND OPERATIONAL PROCEDURES

Issuance Date: February 14, 1958

CIVIL EFFECTS TEST GROUP

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Operation PLUMBBOB Preliminary Report

Project 32.3

EVALUATION OF COUNTERMEASURE SYSTEM COMPONENTS AND OPERATIONAL PROCEDURES

By

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November 1957

ABSTRACT

The objective of Project 32.3 was to evaluate some operational characteristics of a radiological shelter and to determine values for some countermeasures-system parameters. The operation consisted of two phases, the first involving measurements made by project personnel in a manned station having the characteristics of a high-performance radiological shelter and the second involving monitoring and reclamation operations in an area near the shelter beginning about 1 hr after burst.

Measurements were made inside the shelter beginning at shot time to (1) test a simple shelter monitoring system, (2) test a proposed ventilation intake configuration intended to eliminate a requirement for filtration of the shelter air supply, (3) determine the effective gamma-radiation shielding afforded by an operational shelter, including two different exhaust ventilation configurations and a simple entrance configuration, and (4) determine those radiation and fallout characteristics needed to evaluate the operational measurements. The second phase involved (1) the test of a key-point initial monitoring technique, (2) the test of two proposed techniques for determining reclamation effectiveness in advance of reclamation operations, (3) the test of the feasibility of achieving a residual number of 0.01 in a cleared area, and (4) the test of a barrier as an alternative to a buffer zone.

Data were obtained on one shot (Diablo). The shelter, having a minimum earth-cover thickness of 3 ft, provided an average shielding reduction factor of about 10,000. All openings in the earth cover for ventilation and other purposes were satisfactory from a radiological point of view with the exception of the straight entrance way. The shelter monitoring system provided adequate information. Because of blast damage to the generator-room wall in the entrance tunnel, a satisfactory test of the ventilation intake configuration was not achieved. All objectives in the second phase were successfully met with one exception. It was not possible to obtain an adequate test of the feasibility of achieving a residual number of 0.01 in the staging area because of the poor condition of the test area.

ACKNOWLEDGMENTS

This project was approved only 16 days before the first readiness date. That the shelter and reclamation areas were constructed, instrumentation installed and calibrated, and dry-runs of the procedure accomplished in time to achieve a very successful participation on shot Diablo was due in large part to the willingness and capability of the participants brought together for the project. The participants were:

USNRDL: A. D. Anderson, H. L. Burge, P. A. Covey, G. W. Gibson, W. M. Home, A. L. Jenks, L. Johnson, R. K. Laurino, J. A. LaSpada, H. Lee, D. MacDonald, C. F. Miller, M. J. Nuckolls, L. G. Porteous, E. Schuert, T. E. Sivley, W. E. Strope, B. A. Sword, G. A. Work.

AEC and Contractors: P. E. Brown, G. Giboney, D. Harris, J. F. Jamison, W. Ogg, H. Osborne, J. Thrall, W. F. Trolenberg, C. Unruh.

Thanks for invaluable aid are also due to R. L. Corsbie, W. W. Schroebel, and E. R. Saunders of the CETG organization and to L. E. Egeberg (Project 32.4), J. E. Barnett (Program 35), and S. Sigoloff (Project 39.1).

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Chapter 1

INTRODUCTION

Project 32.3 was originally proposed as a field test of considerable size designed to proof-test on a convenient scale the radiological defense system developed at the U. S. Naval Radiological Defense Laboratory[1,2] and, at the same time, to permit the training of 50 to 100 representatives of AEC installations in the planning and implementing of the radiological defense system at their home stations. The required test conditions could not be obtained; however, since the need for information in the area of radiological defense was judged to be acute, it was decided to attempt to obtain the more urgently desired information on the performance of certain important components of the system even though the conditions available were not optimum. Accordingly, the training objective was abandoned, and a technical project of greatly reduced scope was proposed.

1.1 OBJECTIVES

The project objective was to evaluate the performance of a number of important components of a radiological countermeasures system in order to fix minimum performance requirements or to establish the feasibility of procedures proposed on theoretical grounds. One group of components is involved in the emergency phase of the system and is associated with a radiological shelter in a fallout area. This group of components was the subject of phase I of the project. A second group of components is concerned with the operational recovery phase of the system and involves operations in the fallout area outside the shelter. This group was the subject of phase II.

1.1.1 Phase I Objectives

All phase I objectives involved measurements made within, and from within, an occupied underground shelter located in the local fallout

area but beyond the region of significant blast damage. These objectives were as follows:

(a) Operational Monitor System: To evaluate the operational suitability and accuracy of a simple low-cost device for determining from within the shelter the radiological situation outside the shelter.

(b) Ingress of Contaminated Air: To evaluate the ability of a simple low-cost configuration of the shelter ventilation system to satisfactorily prevent the entry of hazardous amounts of radiological fallout into the shelter and to determine whether or not filtration of the air supply would be a requirement of shelter design.

(c) Effects of Openings on Shielding: To evaluate the effective shielding provided by an underground shelter and to determine the effect of the shelter entrance and two different ventilation-opening configurations on the effective shielding.

(d) Supporting Technical Studies: To obtain information on radiological decay, energy spectra, and physicochemical characteristics of fallout necessary to interpret the results of the operational measurements.

1.1.2 Phase II Objectives

Phase II objectives involved measurements outside the shelter following phase I. Most objectives are concerned with the establishment of a suitable staging area for operational recovery. These were as follows:

(a) Initial Monitoring from Shelter: To evaluate a standard procedure for determining essential radiological information in a minimum amount of time and with a minimum exposure of personnel.

(b) Staging-area Reclamation: To establish the feasibility of achieving a residual number of 0.01* in the major portion of a cleared staging area and to determine the operational residual numbers associated with this effort.

(c) Reclamation Test Methods: To obtain an initial feasibility judgment on two techniques, proposed on theoretical grounds, for determining the effectiveness of a reclamation method on a small representative area before committing personnel to a large-scale operation.

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* Residual number is a measure of radiological countermeasure effectiveness and is defined as the ratio of the measurement with the countermeasure to the corresponding measurement without the countermeasure.

(d) Alternative Buffer-zone Techniques: To determine the relative effectiveness, as a function of effort expended, of a barrier technique vs. a buffer-zone method.

1.2 BACKGROUND

The radiological defense system consists of three time phases of action following a contaminating nuclear event: (1) emergency phase, (2) operational recovery phase, and (3) final recovery phase.[1] The technical basis for this phasing lies principally in the manner in which the gamma-radiation hazard decreases with increasing time after burst. In general, the gamma radiation decays very rapidly at early times and more and more slowly at later times after burst. Operations, consequently, must be geared to this decay rate. There exists a time period immediately following the arrival of fallout in which the gamma-radiation hazard is so high that no unshielded operations are feasible without casualties (or without exceeding the allowable personnel exposure). This time period constitutes the emergency phase, as shown in Fig. 1.1. All operations during this phase must take place in shelters that provide adequate shielding against the gamma radiation. The fundamental objective during this phase is the survival of personnel. Therefore, adequate personnel shelters are the minimum requirement for defense during this phase.

At some time after fallout has ceased, the gamma-radiation hazard will have decreased to the point where short-term unshielded operations are feasible, although long-term or normal functions are not. At this time the ability to perform short-term functions can be used to create the necessary conditions for the resumption of the longer term functions. The principal means available for this purpose is reclamation. This time period, which has as its objective the recovery and operation of the essential unprotected facilities, is the operational recovery phase.

At a much later time, about one to two years for most of the contaminated area, the gamma-radiation hazard will have decreased to a level where it is no longer significant. This may be conveniently taken as the level at which the present AEC peacetime permissible exposure of 0.3 r/week would not be exceeded. The final recovery phase will begin at this time and will continue indefinitely. Non-essential areas bypassed during the operational recovery phase can then be reoccupied. External gamma radiation would no longer be a significant hazard, but the control of the internal alpha- and beta-radiation hazards could constitute a major public-health problem.

The process of radiological defense is thus a phased system in which shelter is the central countermeasure in the emergency phase; reclamation, in the operational recovery phase; and contamination control, in the final recovery phase. Operationally, personnel would

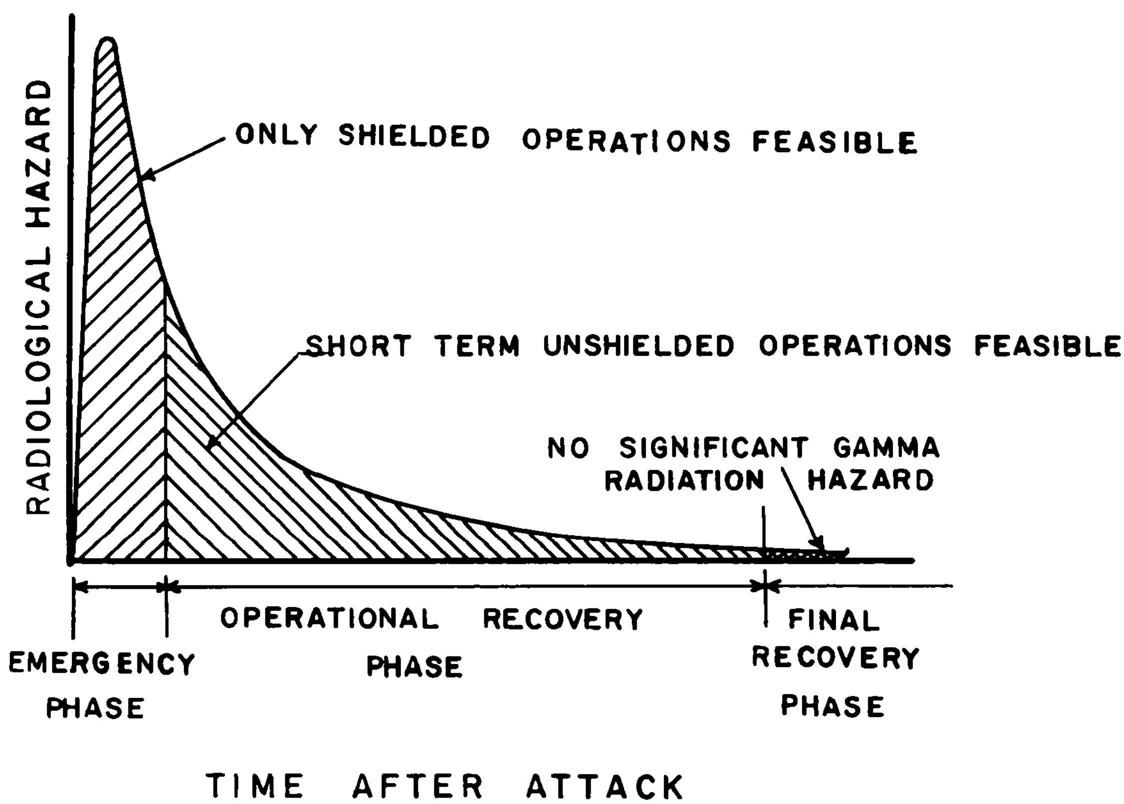

Fig. 1.1— Phases of radiological defense.

seek shelter first. After several days to a week in shelter, a limited group of trained personnel would emerge and establish safe areas from which to stage recovery of the essential area. Essential facilities would then be recovered by a second group of trained personnel operating from the staging area. Essential functions would then be performed while further enlargement of the recovered area was being undertaken. One to two years later, relative freedom of action and movement would become possible, subject to contamination-control restrictions.

Considerable work has been done to develop the concepts of the system and to develop the necessary components of the system.[3-5] Work has reached the point where a full-scale test is desirable to proof-test the developed components and to establish minimum requirements for those components yet undetermined. To obtain an adequate test, participation in a low-yield surface detonation was required. Efforts to obtain this type of burst in Operation Plumbbob were not successful. A careful study of the shots approved for the operation showed that none was suitable for a full-scale test of the system. However, a number of tower shots offered an opportunity for gathering needed information on radiological shelter design and on establishment of a staging area. In addition, some opportunity would be presented for a study of some of the operational parameters inherent in the emergency and early operational recovery phases.

Considerable thought and study was given to the location of the shelter at the test site to ensure fallout on the shelter. Wind data for the past five years were studied in an effort to allow prepositioning of the shelter in an area likely to receive contamination. From these data it appeared that the highest probability of receiving fallout would be obtained by locating the shelter in the sector 360 to 20 deg, or on a line 10 deg east of north. At the best location, chances of success were still only one in five.

It was obviously necessary to schedule participation in a number of shots to increase the changes of success. Three shots (Diablo, Shasta, and Whitney) were found to occur in the same area, and participation in all three shots would make the chances of a successful run at the shelter about one in two. Therefore participation was scheduled definitely for Diablo and Shasta, with participation in Whitney and possibly other shots conditional on the success or failure of the earlier participations.

The shelter (a standard ammunition-storage magazine of the type previously tested to 25 psi) was located in the most probable fallout area at a distance where the predicted blast overpressure would not exceed 3 psi. Average gamma-radiation intensity anticipated at this range (assuming that the shelter was downwind) was about 100 mr/hr measured at 1 hr after burst; maximum radiation intensity expected was about 1 r/hr measured at 1 hr. Since fallout arrival time would be a matter of minutes after burst, much higher transient intensities were

anticipated. Nevertheless, the relatively low levels of fallout anticipated indicated that measurements within the shelter would be difficult and that phase II operations must be accomplished beginning about 1 hr after burst. These conditions influenced the choice of objectives and the experimental procedure.

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1. W. E. Strope, Radiological Defense Measures as a Countermeasure System, Report USNRDL-TR-74, Feb. 15, 1956.
2. NavDocks TP-PL-2, Atomic Warfare Defense, July, 1, 1956.
3. NavDocks TP-PL-13, Radiological Recovery of Fixed Military Installations, June 1, 1957
4. W. E. Strope et al., Operation JANGLE Report, WT-400.
5. USNRDL Technical Report in preparation reporting the Camp Stonemen experimental program of September 1956.

Chapter 2

PROCEDURE

2.1 GENERAL PLAN

The operating area for the project is shown in Fig. 2.1. The general procedure was to man the shelter on D-1 night with designated personnel (about 15 people). At H-30 min mechanical ventilation was shut down, and blast closures were secured on all openings. Shelter status was reported to the Control Point at required intervals via phone (Appendix C). Telephone link was backed by emergency radio link. Immediately after the detonation, closures were removed, and ventilation was activated. Predicted fallout arrival time was 6 to 10 min after burst. The intensity was expected to peak about 20 min after burst, and fall-out was expected to be complete approximately 30 min after burst. Phase I measurements were made during the first hour. Approximately 45 min to 1 hr after burst, the exact time depending on the radiological situation resulting at the shelter, the phase II initial monitoring routine was carried out. Information obtained was relayed to the shelter by voice radio. If none of the three pre-located areas had received a suitable level of fallout, no operations would be conducted on that shot.

Phase I operations were conducted inside the underground radiological shelter (Fig. 2.2). The shelter, a standard 25- by 48-ft Armco Multiplate ammunition-storage magazine, was modified as shown in Fig. A.1. The new entrance unit, containing a Navy standard quick-acting watertight door and two hooded ventilation intakes was reached by an open ramp and a covered passageway approximately 30 ft long (Fig. 2.3). The shelter was buried side-on to the shot area beneath 3 ft of earth cover, the entrance facing away from Ground Zero. The roof of the shelter housed two exhaust ventilators of differing configuration, two dosimeter tubes, a periscope housing, and an antenna lead tube. A small buried sample-collection room was located adjacent to the end of the shelter which was opposite the entrance. It was entered from the shelter through a crawl space. The shelter was ventilated by two M6 collective protectors, with a total capacity of

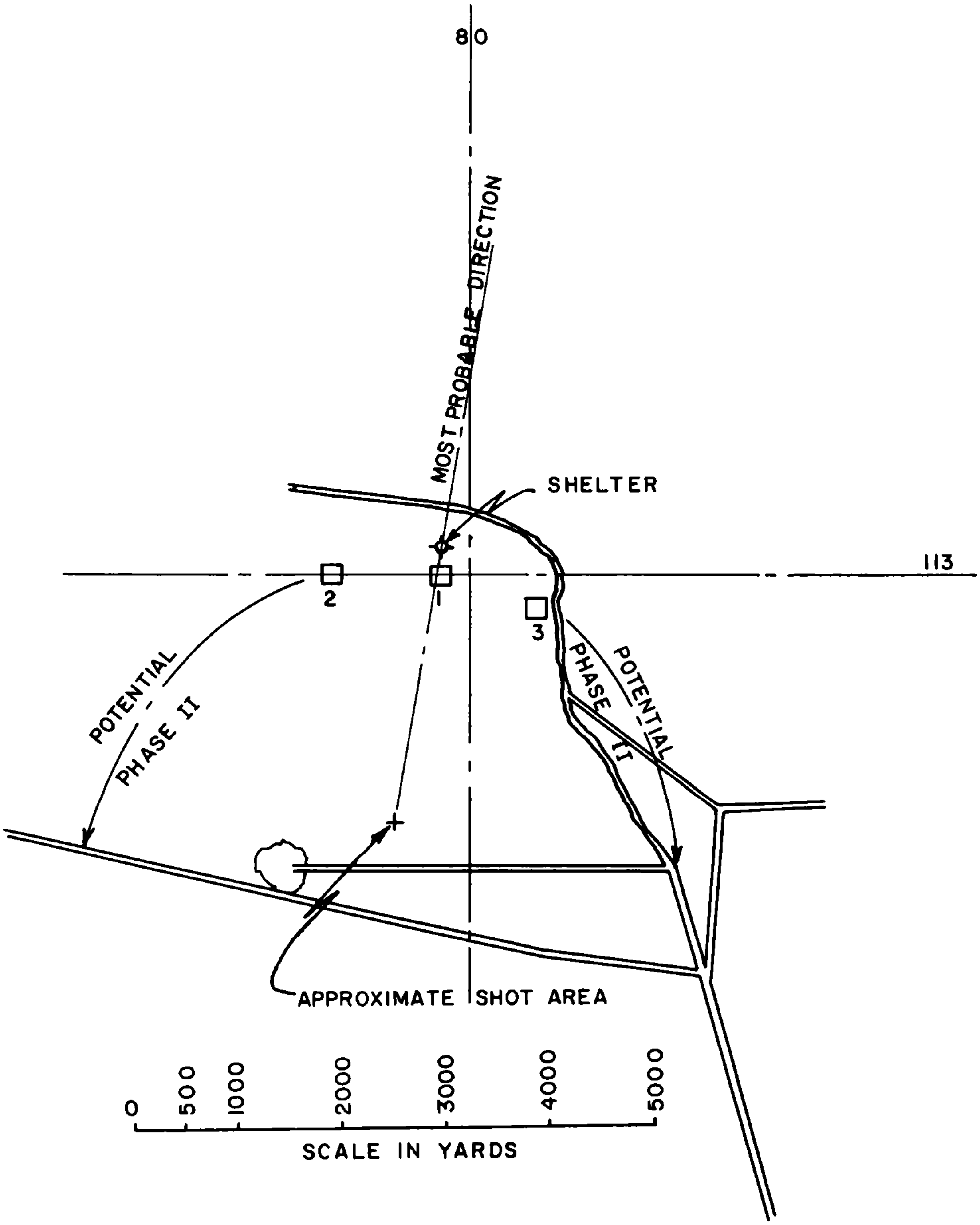


Fig. 2.1—Operating area.

Fig. 2.2--View of shelter, looking toward shot area.

Fig. 2.3—Entrance ramp, showing tunnel opening.

600 cfm. Design details of the shelter are given in Appendix A.

Phase II operations were conducted in an area measuring 500 ft on a side. Three such areas were predesignated and staked prior to shot time. These areas are shown in Fig. 2.1. The areas offered very difficult conditions for land reclamation, as compared with areas reclaimed at Operation Jangle[1], because of the rocky condition of the soil and the presence of gullies and washes. Because of this, extensive preparation of the areas was necessary to provide even minimum conditions for successful land reclamation by scraping. Large numbers of stones and boulders were removed from these areas. Even with these efforts, scraping was substituted for plowing as the only practicable buffer-zone method. Land-reclamation equipment and other vehicles were located about 3 miles SW of the shot towers, and the jeeps were located to the rear of the shelter near the entrance. The jeeps were revetted and covered with tarpaulins during the fallout event.

2.2 OPERATIONAL MONITOR SYSTEM

Objective I(a) involved the evaluation of the low-cost monitoring device shown in Fig. 2.4. The system consists of a 1-in steel pipe projecting above the shelter roof that is fitted with a wooden rod drilled at the upper end to receive a standard IM-9 self-reading dosimeter. The dosimeter is charged within the shelter, run up to the exposed position for a measured period of time, and withdrawn; the dose is then read. The gamma-radiation intensity is obtained by the following relation:

$$I = \frac{D \times 60}{t}$$

where I is the intensity in roentgens per hour, D is the dose in roentgens as read on the dosimeter, and t is the time of exposure in minutes.

The value of I thus calculated is associated with the time after burst corresponding to the mid-point of the exposure period. The experimental procedure involves a variable exposure period ranging between 1 and 6 min, depending on the dose recorded on the previous exposure, and a constant 1-min down time while the dosimeter is being read, the reading is being recorded, and the dosimeter is being recharged, if necessary.

Two such systems were fitted in the shelter for purposes of intercomparison, one at each end of the shelter. The forward dosimeter tube is shown in Fig. 2.5. The exposure schedules for the two systems were arranged to provide exposure by one system during the down time of the other system, thus providing better resolution of the arrival time and peaking time.

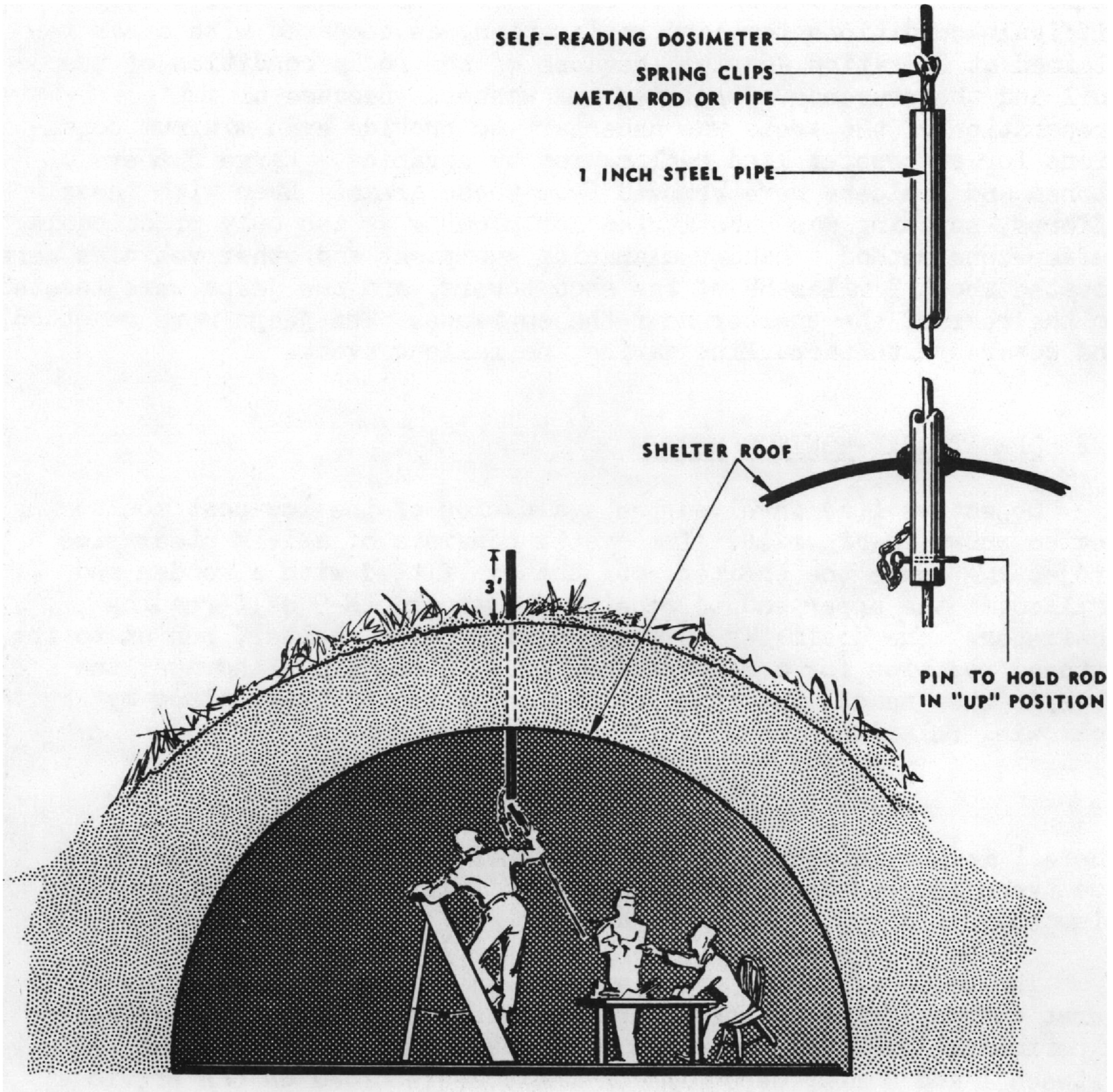


Fig. 2.4--Simple radiation-measuring device for use in shelter.

Fig. 2.5--Exterior view of forward dosimeter tube.

The following information was to be obtained from the system:

(a) Time of arrival of fallout
(b) Time and absolute value of peak intensity
(c) Time of fallout cessation
(d) A prediction of the standard intensity (roentgens per hour at 1 hr) based on readings taken at about fallout cessation (about 30 min after burst).

Items (a) and (b) were obtained directly from the intensity measurements. Items (c) and (d) were obtained by correcting the intensity measurements to 1 hr by means of the decay curve shown in Fig. 2.6. Information obtained was evaluated following the event by comparison with data obtained under objective I(d) and by Project 32.4.

2.3 INGRESS OF CONTAMINATED AIR

Objective I(b) was concerned with the evaluation of a simple ventilation intake configuration for the shelter that previous experiments had indicated should prevent significant amounts of fallout from entering the shelter (Fig. A.1). Air is drawn through the entrance tunnel, which acts as a plenum chamber. At the shelter, two intakes, protected by mushroom heads that force a reversal of air direction, are located adjacent to the door. Air is taken into the shelter by two M6 collective protectors,[2] delivering a total volume of 600 cfm (Fig. 2.7). Air velocity across the face of the entrance tunnel is approximately 30 ft/min. The combination of low air velocity in the tunnel and mushroom vent caps on the air intakes was the configuration being tested.

The ingress of contaminated air through the configuration was determined from activity collected on the particulate filters in the collective protectors. These measurements were to be made at USNRDL after shot participation.

To further define the conditions of test so that the results could be evaluated for other contaminating events, it was necessary to relate the activity concentration in the air moving through the system to the activity concentration in the air external to the shelter. For this purpose, measurements were made both inside and outside the shelter to determine the activity concentration as a function of time and the average activity concentration during the fallout period.

Four aerosol sampling units and two collective protector units were used to obtain the data. Two aerosol sampling units (1 automatic incremental sampler and 1 Portovac sampler) were placed outside the shelter entrance (Fig. 2.8) to measure activity concentration with time and total activity during the fallout period in the open atmosphere. Two sampling units (both Portovac samplers) and the M6 units were

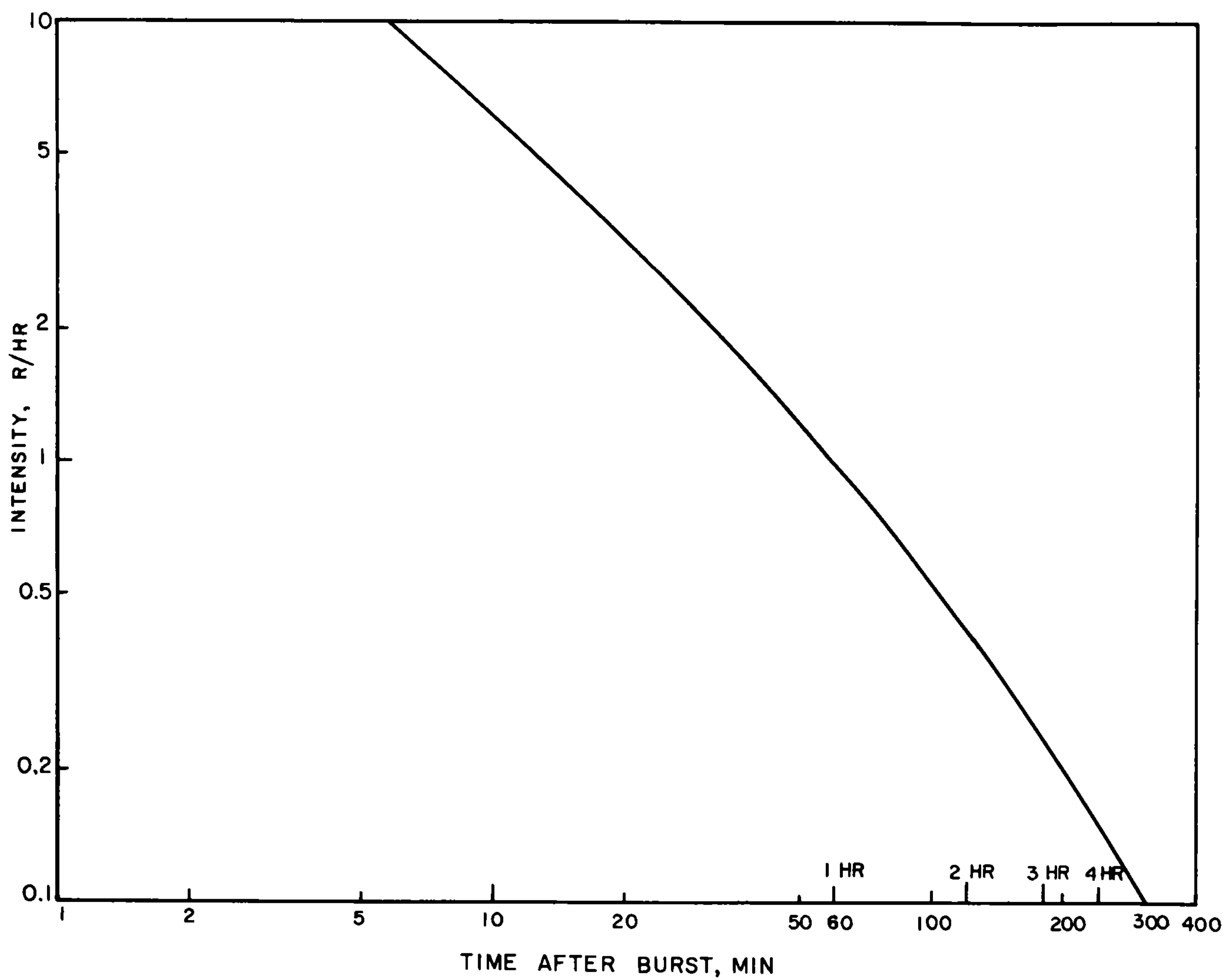


Fig. 2.6--Planning decay curve, normalized to unit standard intensity.

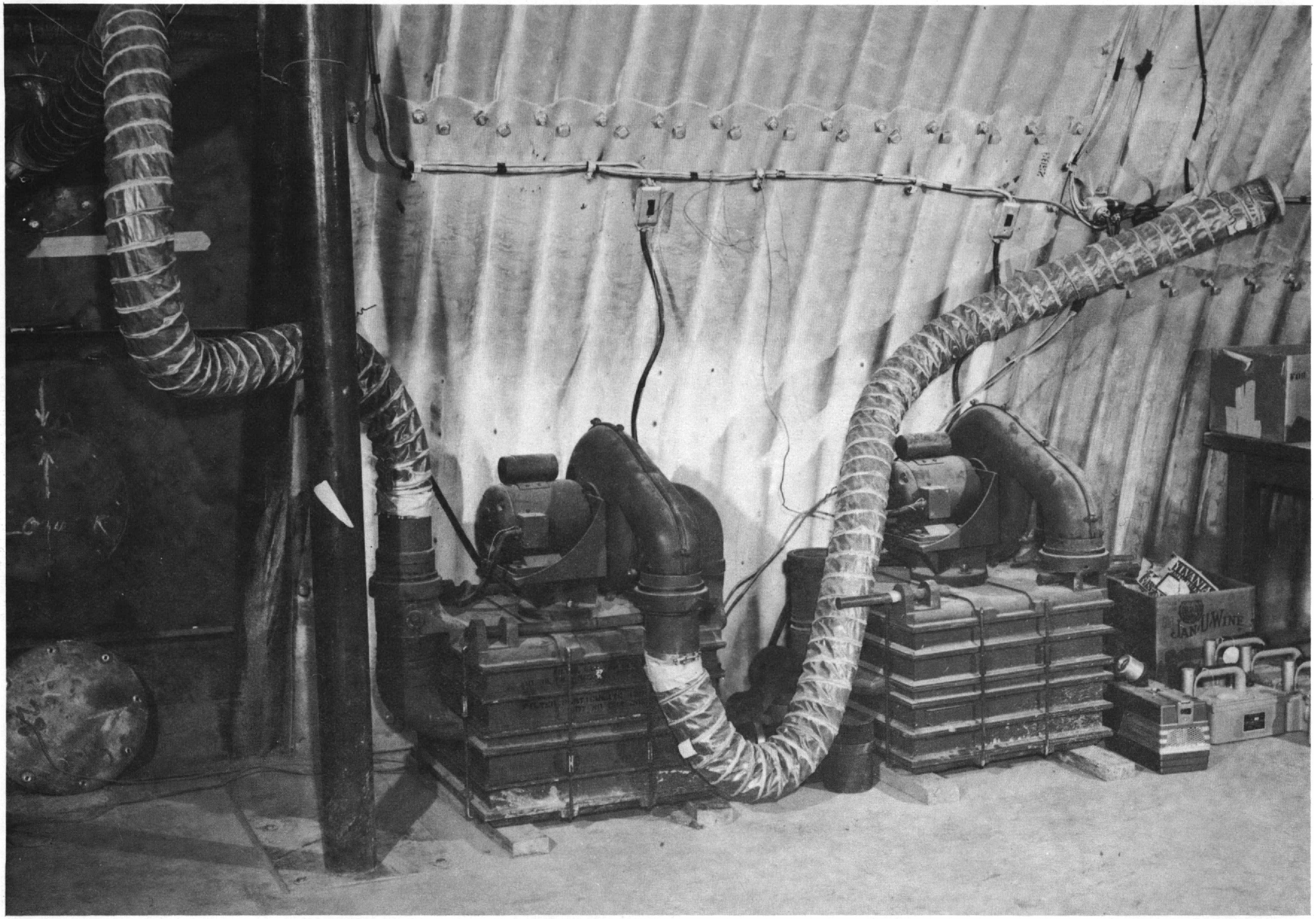


Fig. 2.7—M6 collective protectors in shelter.

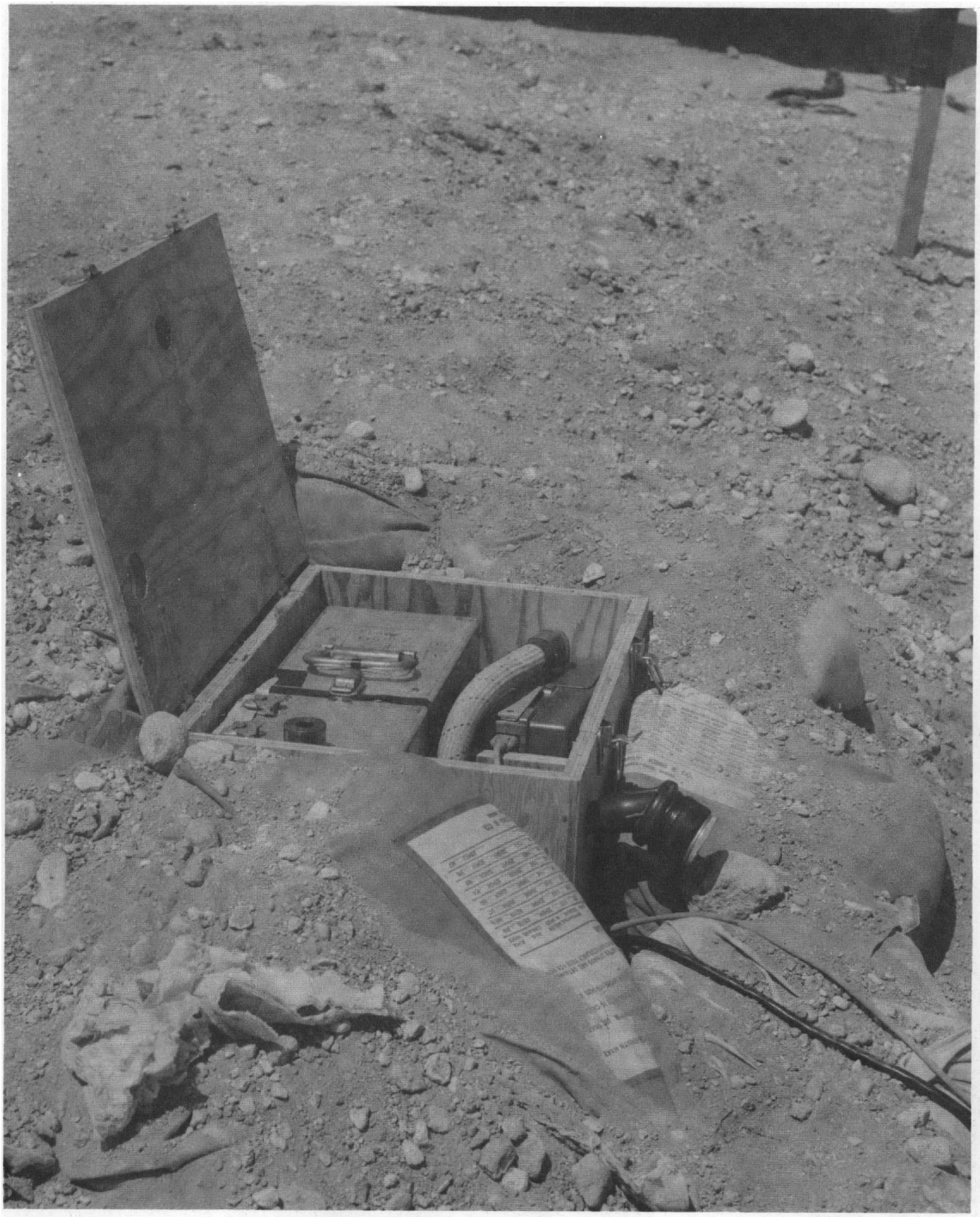


Fig. 2.8--Exterior air samplers near shelter entrance.

located inside the shelter. One sampler was used to measure the activity concentration in the plenum chamber through an opening in the door, and the other unit was used to measure the activity concentration in the intake of the M6 unit (Fig. 2.9).

Aerosol sampling began when fallout reached the vicinity of the shelter (indicated by the Project 32.4 gamma intensity-time recorder (GITR) located outside the shelter). At this time outside samplers were switched on. The two samplers inside the shelter were operated for sampling periods of 2-min duration with 1-min intervals between sampling periods. Filters from shelter samplers were replaced after each sampling period and stored for counting after the end of the fallout event.

Aerosol sampling inside and outside the shelter was stopped shortly after the end of the fallout event. When the intensity outside the shelter permitted, personnel recovered the filters from the outside samplers for counting.

2.4 EFFECTS OF OPENINGS ON SHIELDING

Objective I(c) was concerned with evaluation of the effective shielding against fallout radiation provided by an underground shelter having approximately 3 ft of earth cover over the crown. It has been pointed out[3] that, although 3 ft of earth cover may be expected to provide a residual number between 0.001 and 0.0005, the effective shielding afforded by an operational shelter will be controlled by openings in the earth cover required for entrances, ventilation ducts, and other shelter appurtenances. In addition, a cylindrical shelter with a level fill will have increasing thickness of earth cover for areas not on the center line.

The shielding effectiveness of the shelter in the vicinity of the air vents and entrance was determined by measurements of gamma intensity and gamma dose inside and outside the shelter and by measurements of the gamma-energy spectrum inside the shelter. On the exterior the needed data were obtained by (1) continuous measurement and recording of intensity and dose at fixed locations above and near the shelter, (2) a gamma survey on and around the shelter, and (3) measurements made by Project 32.4 on total and incremental fallout collectors around the shelter. Inside the shelter data were obtained by (1) measurement of gamma intensity and dose at a few fixed stations, (2) survey measurements at a large number of other stations distributed throughout the shelter, (3) a directional gamma-radiation survey along the center line of the shelter, and (4) measurements of gamma-energy spectra using a single-channel pulse-height analyzer.

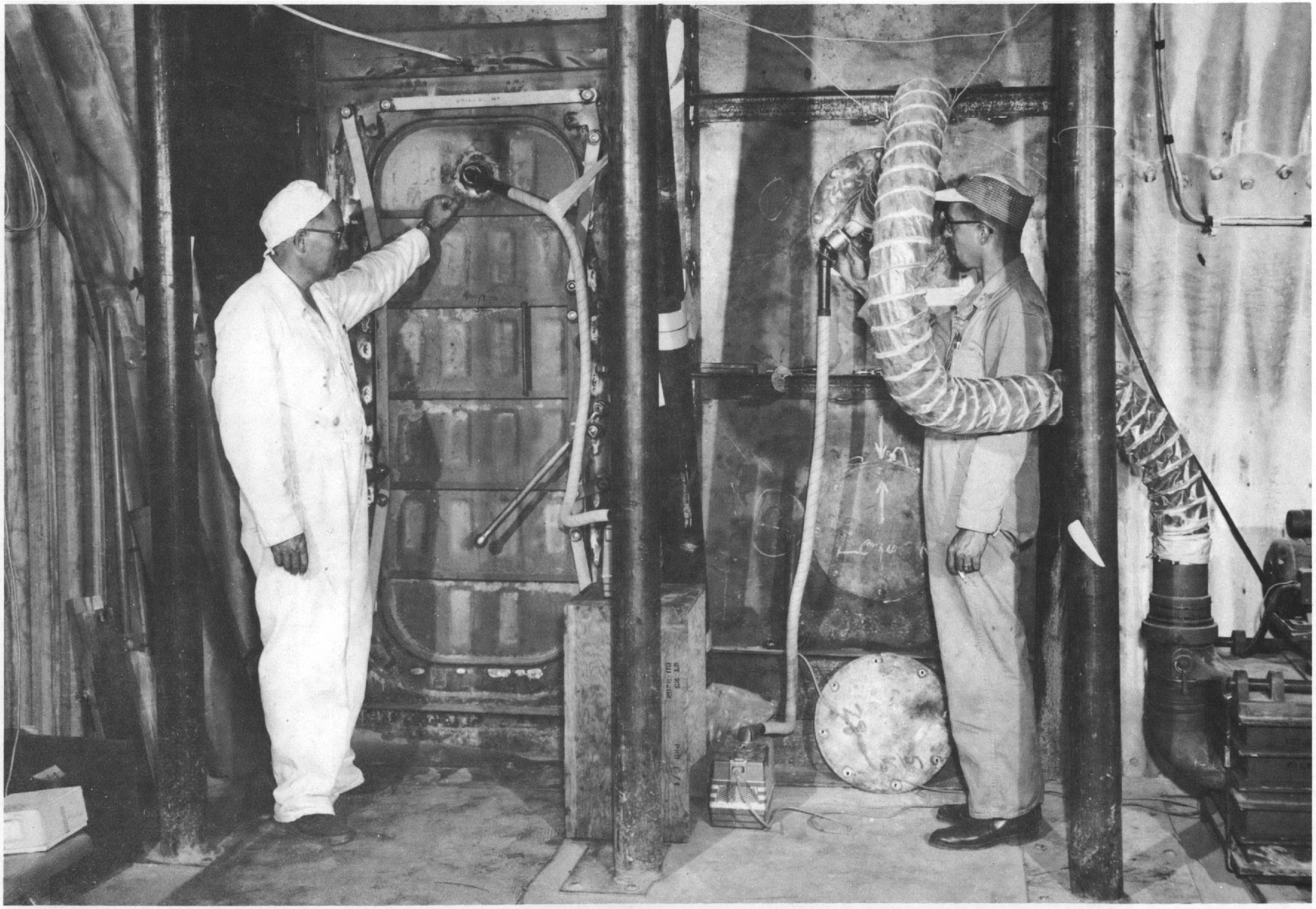


Fig. 2.9--Interior air sampling arrangement.

2.4.1 Dose Measurements

Dose measurements outside the shelter were made with film-badge dosimeters. Film badges were secured near the top of the dosimeter tubes (about 2 ft 6 in. above the ground) and to the center ventilator (about 6 in. above the ground) (Figs. 2.5 and 2.10). These dosimeters were collected upon completion of phase I; they recorded the dose both from initial gamma radiation and from fallout up to the time of collection. About 2 min after burst, when the dose from initial gamma raidation had been received, another set of film badges was introduced into the above locations from inside the shelter. Several film badges were pushed up each dosimeter tube and dropped into a cup attached near the top of the tube (Fig. 2.5). Other film badges attached to metal rods were pushed up the center vent to an exposed location. These badges recorded only fallout dose and were collected at the same time as the original group. The difference between the doses recorded by the two sets of badges was attributed to initial gamma radiation.

A limited number of dose measurements were made inside the shelter. Because of the high degree of protection afforded by the shelter, film-badge dosimeters were too insensitive to be used. Near shelter openings, where the highest doses were expected, self-reading electroscope dosimeters (0 to 200 mr) were used. A line of dosimeters was strung vertically below the ventilation openings. Measurement heights on the vertical line were 3, 6, 9, and 12 ft above the shelter floor. Three dosimeters were located near the shelter door. All self-reading dosimeters were read about 2 min after burst to determine the dose from initial gamma radiation; final readings were made at the completion of phase I.

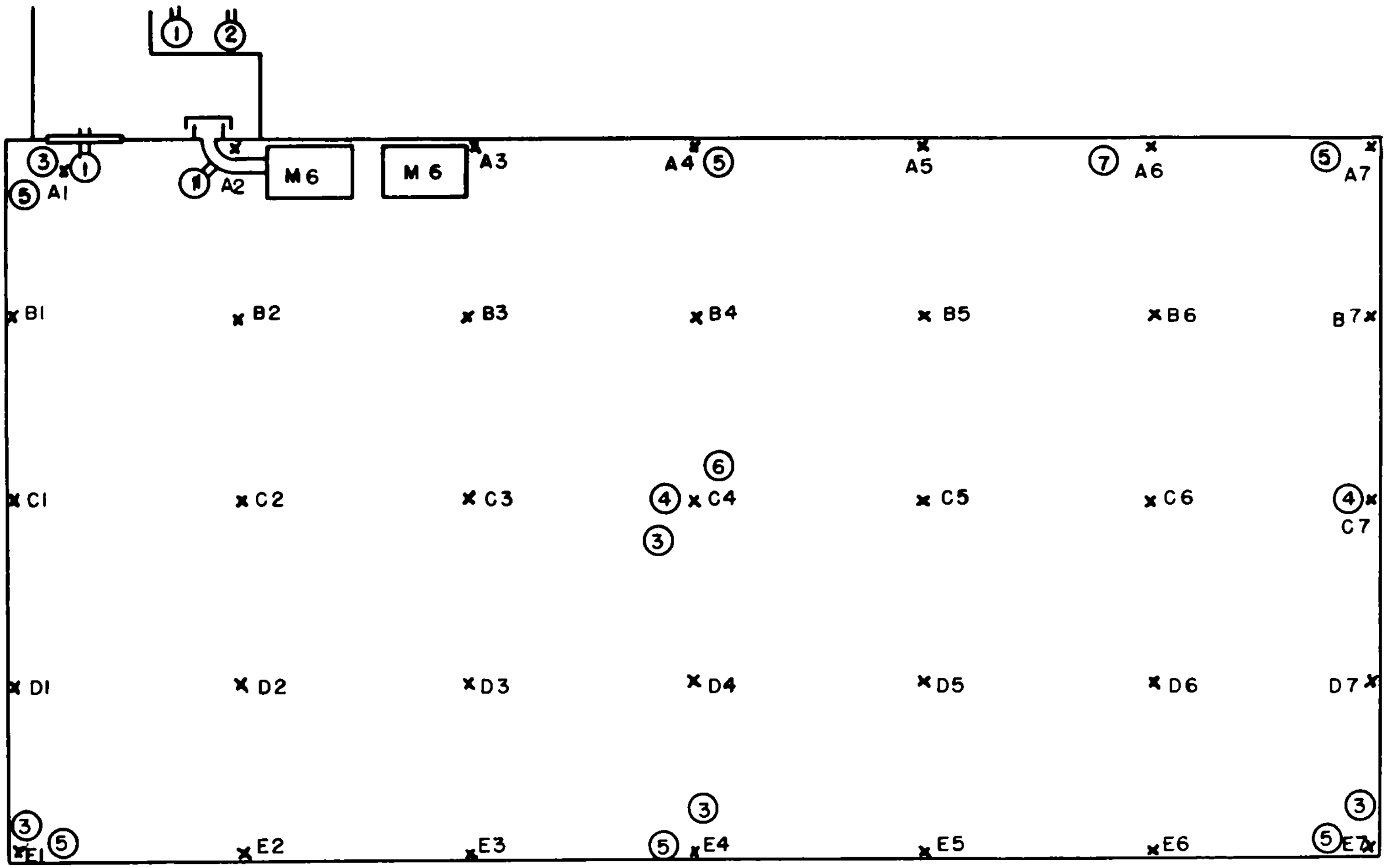
In addition to the above, a number of Victoreen background dosimeters (0 to 10 mr) were charged by a manometer charger-reader about 2 min after burst and were placed in the well-protected parts of the shelter to measure the anticipated low doses at these points (Fig. 2.11).

2.4.2 Intensity Measurements

Continuous measurement of intensity at a fixed location on top of the shelter (Fig. 2.12) was provided by a Project 32.4 GITR with the recording console inside the shelter. This instrument was switched on 2 hr before shot time and continued to record until the completion of phase II.

About 1 hr after burst, depending on the radiological situation, a gamma-intensity survey was made using the AN/PDR 27C survey meter at the points shown in Fig. 2.13. At the time these measurements were made, the top of the center exhaust vent was decontaminated by broom, and sandbags were piled around the vent to reduce the contribution of

Fig. 2.10--View of center ventilator, showing location of film-badge dosimeters.



✕ SURVEY STATION
(1) PORTOVAC AIR SAMPLER
(2) CYCLIC AIR SAMPLER
(3) CONTINUOUSLY RECORDING AN/PDR-27C
(4) DOSIMETER STRING AT VENT
(5) BACKGROUND DOSIMETER
(6) GM COUNT METER
(7) PULSE HEIGHT ANALYZER

Fig. 2.11--Location of instruments and survey stations inside shelter.

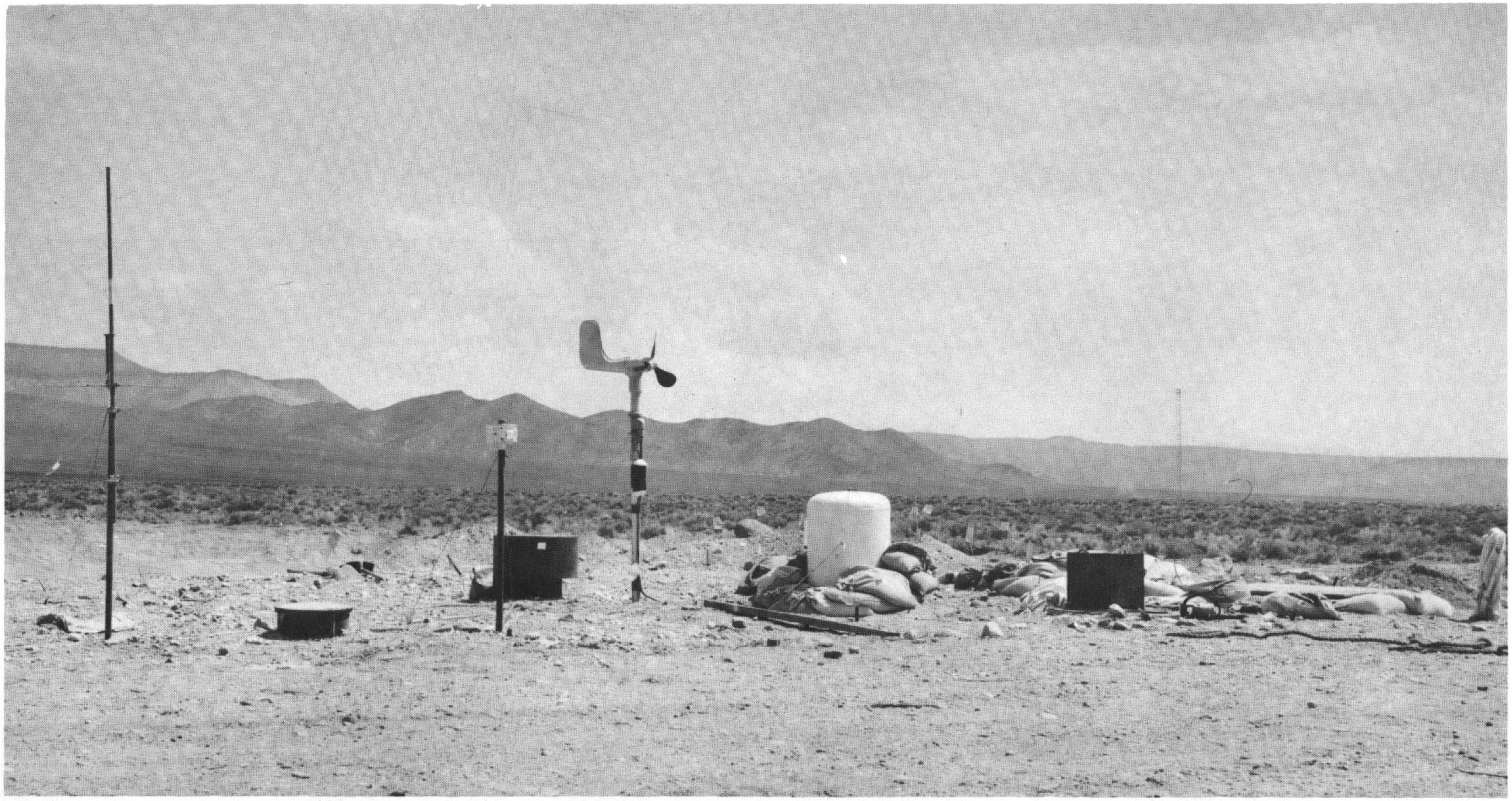


Fig. 2.12--View of instrument location on top of shelter, showing (left to right) antenna, periscope housing, after dosimeter tube, rear exhaust vent, recording anemometer, GITR, sample elevator, and incremental collector.

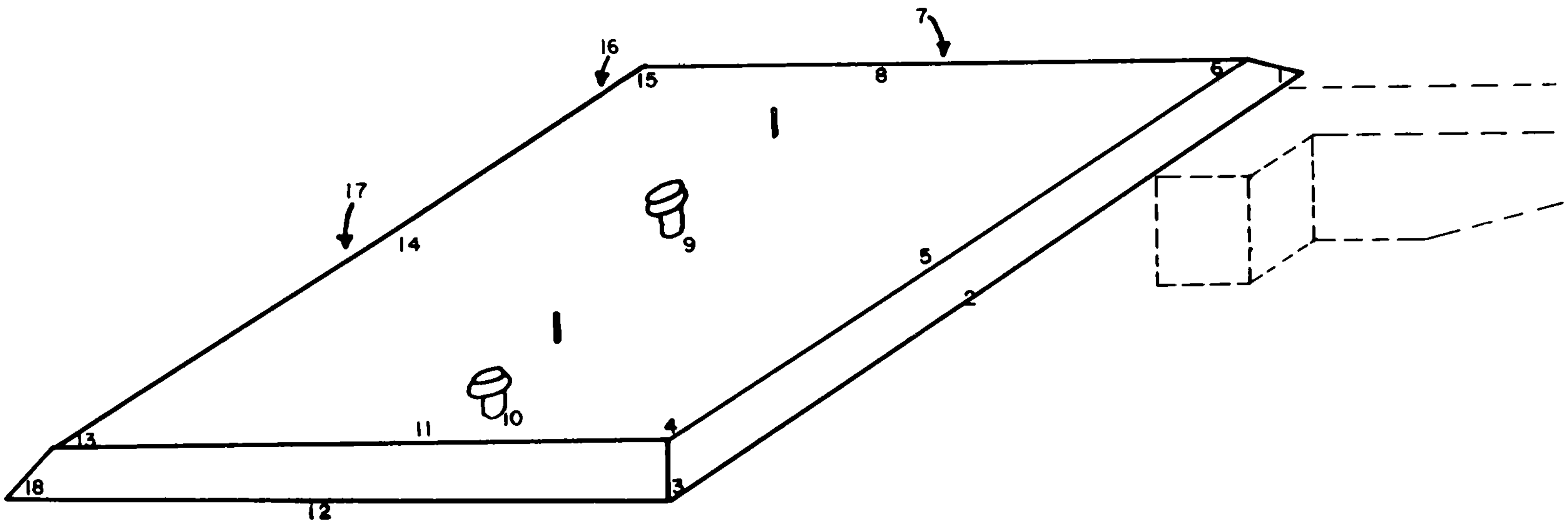


Fig. 2.13--Location of exterior measurement stations.

the vent to the radiation field inside the shelter to a low level. A second survey was then performed within the shelter.

Intensity measurements inside the shelter were made using modified AN/PDR 27C instruments. Seven such instruments were connected by cables to one 12-channel Heiland recorder. These instruments were used to take detailed survey measurements at a large number of survey stations inside the shelter. The survey was initiated after fallout cessation (about 30 min after burst). Initially, monitors lined up at stations in row A (stations A1, A2, A3, etc., in Fig. 2.11). On signal, all monitors read the instrument at the 3 ft height above floor and recorded the readings. At the same time the instruments were recorded for 10 sec on the Heiland recorder. Monitors then moved to row B, and the process was repeated. Measurements were also made at other heights of interest (6, 9, and 12 ft above the floor). A second survey was made after the center vent had been shielded.

In addition to the above, AN/PDR 27C instruments, modified to record individually on Brown recorders, were located as shown in Fig. 2.11; they recorded continuously.

2.4.3 Directional Measurements

The source of radiation inside the shelter was investigated with a directional gamma-intensity meter (see Appendix B). Measurements were initiated at fallout arrival time at locations along the center line of the shelter (row C). At each location the instrument was rotated in a plane including the nearest shelter opening (entrance or ventilators).

2.4.4 Energy-spectrum Measurements

A single-channel pulse-height analyzer (Appendix B) was located at position A6. This instrument was used intermittently to determine the gamma spectrum at this point within the shelter.

2.5 SUPPORTING TECHNICAL STUDIES

Objective I(d) included a series of precise measurements to define more completely the radiological situation at the shelter. The instrumented area on top of the shelter is shown in Fig. 2.12.

2.5.1 Interval-collector Data

Two interval collectors placed near the shelter were activated at about H+2 min. The collecting surface was a grease-covered plastic

disk about 3 in. in diameter. Each disk was exposed for a period of 1 min, and the collectors were operated to collect fallout up to about H+1 hr. At about H+2 hr, Project 32.4 personnel recovered the samples and returned them to USNRDL for analysis. These analyses were used to determine the time of arrival of fallout at the shelter, the rate of arrival of fallout, the time of cessation of fallout, and, together with the GITR records and decay measurements, the transit dose at the shelter. In addition, the samples were used to determine the range of fallout-particle sizes at the shelter.

2.5.2 Early-time Decay of Fallout Samples

Samples of fallout were collected by aluminum and plastic hexcell collectors and a hand-operated elevator located in the shelter sample room. An aluminum tray was exposed at H-30 min and retrieved at H+2 min as a collection of possible throw-out material. After recovery of the aluminum tray, a 6- x 6-in. hexcell collector was placed on the elevator and raised into collecting position. As soon as the GITR recorders showed a rapid rise in the field intensity, the first hexcell was recovered and a second was exposed. The second hexcell collector was exposed until cessation of fallout (or until such time as the first sample had decayed to a low level).

Decay of the samples was measured in the USNRDL 4-pi ion chamber, an argon-gas ionization chamber operated at 600 psig with a previously determined photon-energy response.[4] Decay was observed for 48 hr, when it was known that the decays of other samples returned to USNRDL were being taken.

2.5.3 Early-time Photon Spectra of Fallout Samples

At H+5 min a helicopter left the CP area and picked up an open-close collector located 75 yards east of the shelter. The sample was returned to the Project 2.2 trailer located at Mercury. A counting sample was prepared, and the first spectrum was taken as soon as possible on the 100-channel analyzer. Spectra were taken at 10-min intervals up to H+1 1/2 hr, at 20-min intervals from H+1 1/2 hr to H+3 hr, and at 1-hr intervals up to H+12 hr. Spectra of fallout samples were also obtained from the single-channel analyzer located in the shelter. These data, together with the decay data and instrument response, were to be used to determine an air-ionization (roentgens per hour) decay curve for the fallout.

2.5.4 Nature of the Fallout

The nature and amount of fallout at the shelter were determined from radiochemical and quantitative analyses made on the six open-

close collector samples exposed above and about the shelter by Project 32.4. The collectors were actuated from within the shelter at H+2 min and closed at H+1 hr (or after cessation of fallout). They were recovered by Project 32.4 and returned to USNRDL by air for analysis. The samples were analyzed for gross gamma activity, gross mass of fallout, fission-product tracer nuclides, induced activities, iron, and soil minerals.

2.6 INITIAL MONITORING FROM SHELTER

The initial effort in phase II was monitoring of the three prelocated reclamation areas. A two-stage key-point monitoring procedure was followed. The first stage was to measure the radiation-field intensity at the center of the area with an AN/PDR 27C. This reading, made at 3 ft above the ground, was reported by radio to the shelter. The single center reading was the basis for selection of the area to be reclaimed. The second stage was to measure and report in a similar fashion the intensity at the four corners of each area. These measurements gave additional information, including the gradient over the area. Radiological information based on these key-point measurements was compared subsequently with the more detailed information obtained in the next step to determine the minimum information required for decisions at the beginning of the operational recovery phase.

2.7 STAGING-AREA RECLAMATION AND TEST METHODS

Objectives II(b) and (c) were accomplished simultaneously. After selection of a satisfactory area, personnel (three supervisors and five monitor-recorders) were dispatched to the area. When these personnel left the shelter, the reclamation-equipment operators (stationed at a more distant location) were alerted to move toward the area. Detailed monitoring was made of the area. Each of four monitors in turn started from the center in the direction of one of the four sides of the area. Readings were made at the center at 3-ft, 2-ft, and 1-ft heights (Fig. 2.14). Each monitor then paced toward his perimeter, taking the 3-ft, 2-ft, and 1-ft measurements at 2 paces and a single 3-ft measurement at 4, 5, 7, 10, 15, 20, 30, and 50 paces and at the 500-ft perimeter line. A fifth monitor took readings at two separate check points outside the area at 15-min intervals during the first hour and at 30-min intervals thereafter. All measurements were recorded along with the time of measurement.

As soon as the survey team had cleared the central area, an area 40 by 40 ft was cleared by motor-grader. Three motor-graders and a motorized scraper were maneuvered into position at the cross-wind side of the 500-ft perimeter line while the above monitoring was being done. They assumed a slant formation, with the scraper at the rear of the slant (Fig. 2.15.) The motor-graders were set for a 2-in. cut at the

Fig. 2.14--Monitors taking measurements in reclamation area.

Fig. 2.15--Procedure used in land reclamation.

40-ft perimeter line, and the blades were set to move the windrow downwind toward the motorized scraper. The first grader cut and built the first windrow, the second grader picked up the first windrow and cut and formed a second windrow, the third grader cut and moved the windrow to the final position. The scraper was set for zero cut and picked up the windrow for disposal beyond the 500-ft perimeter. Two passes were needed to create a 40- by 40-ft cleared area since the width from the forward edge of the first grader to the rear edge of the third grader was 20 ft.

The 40- by 40-ft cleared area was then surveyed by conducting the previous survey to the edge of the cleared area.

Next, the cleared area was enlarged to 60 by 60 ft by making a 10-ft pass around the 40- by 40-ft area. Sides were done in order north, south, west, and east. The windrow was left at the outer edge by the graders and picked up by the scraper. The 60- by 60-ft area was then surveyed as before.

Finally, the area was enlarged to 100 by 100 ft by making a 20-ft pass around the previously cleared area. Several trips of the scraper were required to remove the 100-ft windrows. The 100- by 100-ft area was then surveyed as before.

The area between the 100-ft perimeter and the 500-ft perimeter (a width of 200 ft) was then scraped, using 3 motor-graders, 2 scrapers, and a follow-up grader. A final survey was then made which was identical with the initial survey.

During the above operations all personnel carried film badges and pocket dosimeters so that operational-dose data could be obtained. The movement of all personnel was timed. If the residual number at the center of the cleared area was greater than 0.01, the area was scraped again and resurveyed. Clearing operations in the 100- by 100-ft area were continued until a residual number of 0.01 was achieved, or until it was obvious that further improvement was impossible.

2.8 ALTERNATE BUFFER-ZONE TECHNIQUE

Objective II(d), concerned with the test of an earth barrier as a substitute for a buffer zone, was conducted separately and at a different time from the operations described in Sec. 2.7. A 100- by 100-ft area was surveyed and then cleared by motor-grader and scraper. The area was then resurveyed. A 3-ft-high earth barrier was then constructed around the periphery of the scraped area by bulldozers. A final survey completed the operation.

REFERENCES

1. W. E. Strope et al., Operation JANGLE report, WT-400.
2. Department of Army Technical Bulletin 3-350-2.
3. A. B. Chilton and L. N. Saunders, "Fallout Radiation Protection Afforded by Below-ground Structures," BuDocks Technical Digest No. 74.
4. C. F. Miller, Response Curves for USNRDL 4-pi Ion Chamber, USNRDL Technical Report, in preparation.

Chapter 3

RESULTS

3.1 GENERAL

Participation occurred in three shots, Diablo, Kepler, and Shasta. Full participation was attempted on the first two shots; participation on Shasta was limited to the acquisition of additional supporting technical data (not reported herein).

3.1.1 Shot Diablo

Shot Diablo was fired on a 500-ft tower 5300 ft south of the shelter at 0430 PDT on 15 July 1957. The predicted wind structure was favorable for fallout at the shelter. Sixteen persons occupied the shelter at the time of burst. The event schedule followed is given in Appendix C. About 1 sec after the shot a light double-peaked ground shock wave was felt; at about 3 1/2 sec the air blast wave arrived. Some dust was raised in the shelter, but no damage was evident. Later it was determined that the only blast damage consisted of the following:

(1) The plywood wall between the entrance tunnel and the motor-generator room was blown in (Fig. 3.1).
(2) The tarpaulins were stripped from the jeeps.
(3) The jeep revetment was partially demolished (Fig. 3.2).

The only damage that affected the experimental results was that to the wall since it caused the motor-generator to draw its cooling air from the entrance tunnel, greatly increasing the flow rate in the tunnel.

Fallout arrival occurred at about 6 min after burst. Intensity rapidly increased to a peak of about 60 r/hr (GITR reading) at about 15 min. Intensity at 1 hr (GITR reading) was 15 r/hr. These intensities were considerably higher than anticipated and forced adjustments in the experimental schedule. Phase II was postponed until

Fig. 3.1--Damage to wall between entrance tunnel and generator room after shot Diablo.

Fig. 3.2--Damage to jeep revetment and tarpaulins after shot Diablo.

D+2 day. Exterior measurements on top of the shelter were made at about 5 1/2 hr after shot time, using AN/PDR T1B high-range radiacs. Shelter personnel left the area at about H+8 hr, two persons remaining to continue data collection.

3.1.2 Shot Kepler

Shot Kepler was fired on a 500-ft tower 4.75 miles south of the shelter at 0450 PDT on 24 July 1957. The wind structure at time of burst was favorable for fallout at the shelter. However, the yield of Kepler was less than anticipated; consequently, fallout was negligible. No useful data were collected on this shot.

3.2 OPERATIONAL MONITOR SYSTEM

Data obtained on the two dosimeter tubes during the first hour after burst are shown in Tables 3.1 and 3.2. Standard intensities shown in the final column were obtained by correcting measured intensities to 1 hr by the decay curve in Fig. 2.6. These data are plotted in Fig. 3.3, along with the intensity-time record obtained by the GITR. Dosimeter-tube data are in good agreement with GITR data, except for the absolute measurements of intensity. It was determined that the three-fold increase in the dosimeter-tube data was due to the collection of fallout in the cups attached to the top of the dosimeter tubes to receive film badges after the initial gamma radiation had been received. These cups were cleaned out during the exterior measurements about 5 hr after burst. Data were again taken and were found to be in good agreement with the exterior measurements and with the GITR reading at the same time. These results are shown in Table 3.3.

Data obtained from dosimeter tubes were evaluated in the shelter during the period of measurement as they would be in an operational shelter. Conclusions drawn were (1) fallout arrived at about H+7 min, (2) peak intensity occurred at about H+15 min, (3) fallout cessation occurred at about H+30 min, and (4) the predicted standard intensity was about 55 to 80 r/hr.

3.3 INGRESS OF CONTAMINATED AIR

Data pertaining to the intake ventilation configuration were obtained from the four air-sampling units and from the particulate filters of one M6 collective protector. The collective protector filters were shipped to USNRDL for measurement, and data are not available at this date. Portovac filter samples were measured at the shelter in the 4-pi ion chamber. Cyclic air-sampler filters were counted at Mercury on the Project 32.1 beta counter. This instrument

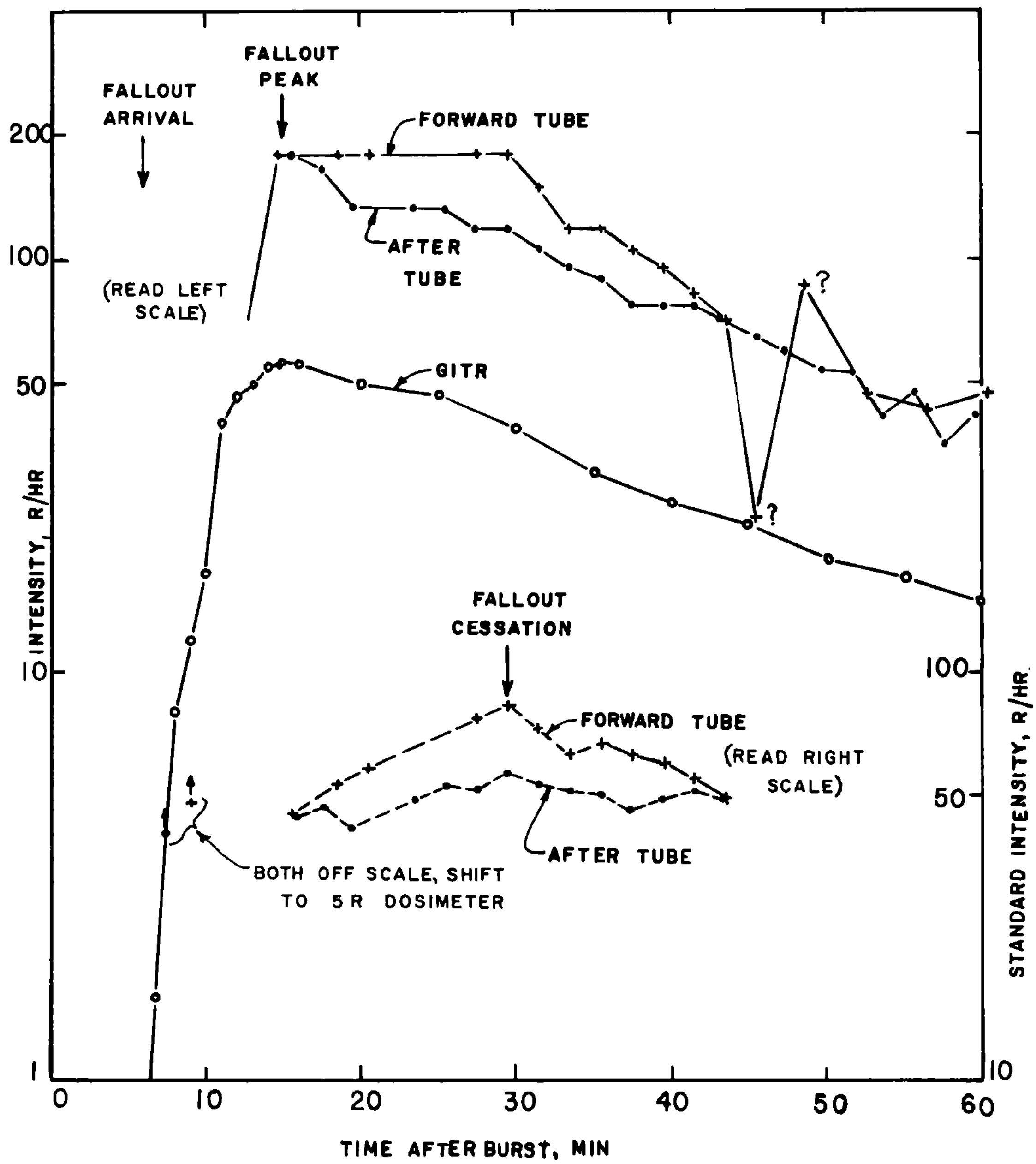


Fig. 3.3--Dosimeter tube results, shot Diablo.

Table 3.1--FORWARD DOSIMETER-TUBE DATA, SHOT DIABLO

Time after burst, min			Exposure period, min	Dosimeter reading, r	Measured intensity, r/hr	Standard intensity, r/hr
Up	Down	Mean				
3	7	5	4	0.04	0.6	0.072
8	10	9	2	0.160+	4.8+	0.072+(off-scale)
14	15	14.5	1	3.0	180	42.0
18	19	18.5	1	3.0	180	53.0
20	21	20.5	1	3.0	180	58.5
27	28	27.5	1	3.0	180	77.1
29	30	29.5	1	3.0	180	83.2
31	32	31.5	1	2.5	150	73.8
33	34	33.5	1	2.0	120	63.4
35	36	35.5	1	2.0	120	66.5
37	38	37.5	1	1.8	108	63.8
39	40	39.5	1	1.6	96	60.0
41	42	41.5	1	1.4	84	55.0
43	44	43.5	1	1.2	72	49.7
45	46	45.5	1	0.4	24	17.0)?
47	50	48.5	3	4.4	88	68.5)
51	54	52.5	3	2.4	48	41.0
55	58	56.5	3	2.2	44	41.0
59	62	60.5	3	2.4	48	48
63	65	64	2	1.2	36	39

Table 3.2—AFTER DOSIMETER-TUBE DATA, SHOT DIABLO

Time after burst, min Up	Down	Mean	Exposure period, min	Dosimeter reading, r	Measured intensity, r/hr	Standard intensity, r/hr
6	9	7.5	3	0.20+	4+(off-scale)	0.51+(off-scale)
15	16	15.5	1	3.0	180	44.5
17	18	17.5	1	2.8	168	46.6
19	20	19.5	1	2.2	132	40.5
23	24	23.5	1	2.2	132	48.8
25	26	25.5	1	2.2	132	52.8
27	28	27.5	1	2.0	120	51.5
29	30	29.5	1	2.0	120	55.5
31	32	31.5	1	1.8	108	53.2
33	34	33.5	1	1.6	96	50.8
35	36	35.5	1	1.5	90	50
37	38	37.5	1	1.3	78	46
39	40	39.5	1	1.3	78	48.5
41	42	41.5	1	1.3	78	50.8
43	44	43.5	1	1.2	72	49.7
45	46	45.5	1	1.1	66	48.2
47	48	47.5	1	1.0	60	45.8
49	50	49.5	1	0.9	54	43.0
51	52	51.5	1	0.9	54	45.0
53	54	53.5	1	0.7	42	37.0
55	56	55.5	1	0.8	48	43.6
57	58	57.5	1	0.6	36	34
59	60	59.5	1	0.7	42	42
61	62	61.5	1	0.5	30	31
63	64	67.5	1	0.7	42	45

Table 3.3—COMPARISON OF INTENSITY READINGS 5 HR 30 MIN AFTER BURST

Instrument	Reading, r/hr
Forward dosimeter tube	2.5
After dosimeter tube	2.1
AN/PDR-T1B at 3-ft height	2.2*
GITR	1.5

*See Table 3.7.

used an end-window Geiger tube and an El-Tronics binary scaler. After being counted at NTS, all filter samples were shipped to USNRDL for more accurate measurement. These data are not yet available.

Measurements made at NTS on the exterior air samplers are given in Table 3.4. Data for the interior air samplers are given in Table 3.5.

A comparison of the NTS data is shown in Fig. 3.4. All samples were corrected for decay to H+2 hr. Decay correction factors were calculated from fallout-sample decay as measured in the 4-pi ion chamber (Fig. 3.13). Cyclic air-sampler data were normalized by setting the sum of the measured activities equal to the activity measured on the total Portovac air sample as follows:

$$\text{Conversion factor} = \frac{\text{total activity on exterior Portovac}}{\text{sum of activity on cyclic air samples}}$$

$$= \frac{355 \times 10^{-10}\ \text{ma}}{5.48 \times 10^{5}\ \text{counts/min}}$$

$$= 6.56 \times 10^{-14}\ \text{ma/count/min}$$

The comparison indicates that the air at the end of the tunnel at the shelter door contained more than twice as much activity as was measured in the open. The hooded ventilation intake reduced this activity by a factor of 2 to 3.

3.4 EFFECTS OF OPENINGS ON SHIELDING

3.4.1 Dose Measurements, Shot Diablo

Film-badge data for outside stations are not yet available. Dose data for interior stations are given in Table 3.6. Three

Table 3.4--CYCLIC-AIR-SAMPLER DATA, SHOT DIABLO
(Counted: July 16, 1957, 8:40 AM to 9:50 AM
Instrument: El-Tronics binary scaler with end-window Geiger tube in lead castle)

Sample No.	Sampling time, min after burst	Net counts/min
1	9 - 11	24248
2	11 - 13	139264
3	13 - 15	108952
4	15 - 17	58424
5	17 - 19	54912
6	19 - 21	70112
7	21 - 23	62352
8	23 - 25	19704
9	25 - 27	7813
10	27 - 29	1916
11	29 - 31	1445

EXTERIOR PORTOVAC TOTAL SAMPLE

Counted: H+6 hr 12 min
Instrument: USNRDL 4-Pi Ion Chamber
Reading: 425×10^{-10} ma
Background: 70×10^{-11} ma

Table 3.5--INTERIOR AIR SAMPLERS

Sample No.	Time of sampling, min after burst	Time of counting, hr after burst	Reading, ma
		Shelter Door Sampler	
1	7 - 9	2:50	200×10^{-11}
2	10 - 12	2:25	480×10^{-10}
3	13 - 15	2:40	587×10^{-10}
4	16 - 18	2:35	350×10^{-10}
5	19 - 21	2:30	320×10^{-10}
6	22 - 24	2:20	315×10^{-10}
7	25 - 27	2:51	495×10^{-11}
8	28 - 30	2:53	Bkgd.
9	31 - 33	2:40	Bkgd.
10	34 - 36	2:43	Bkgd.
11	37 - 39	2:45	Bkgd.
		M6 Intake Sampler	
1	7 - 9	3:30	Bkgd.
2	10 - 12	3:30	720×10^{-11}
3	13 - 15	3:30	132×10^{-10}
4	16 - 18	3:30	745×10^{-11}
5	19 - 21	3:30	610×10^{-11}
6	22 - 24	3:30	445×10^{-11}
7	25 - 27	3:30	198×10^{-11}
8	28 - 30	3:30	142×10^{-11}
9	31 - 33	3:30	230×10^{-11}
10	34 - 36	3:30	Bkgd.

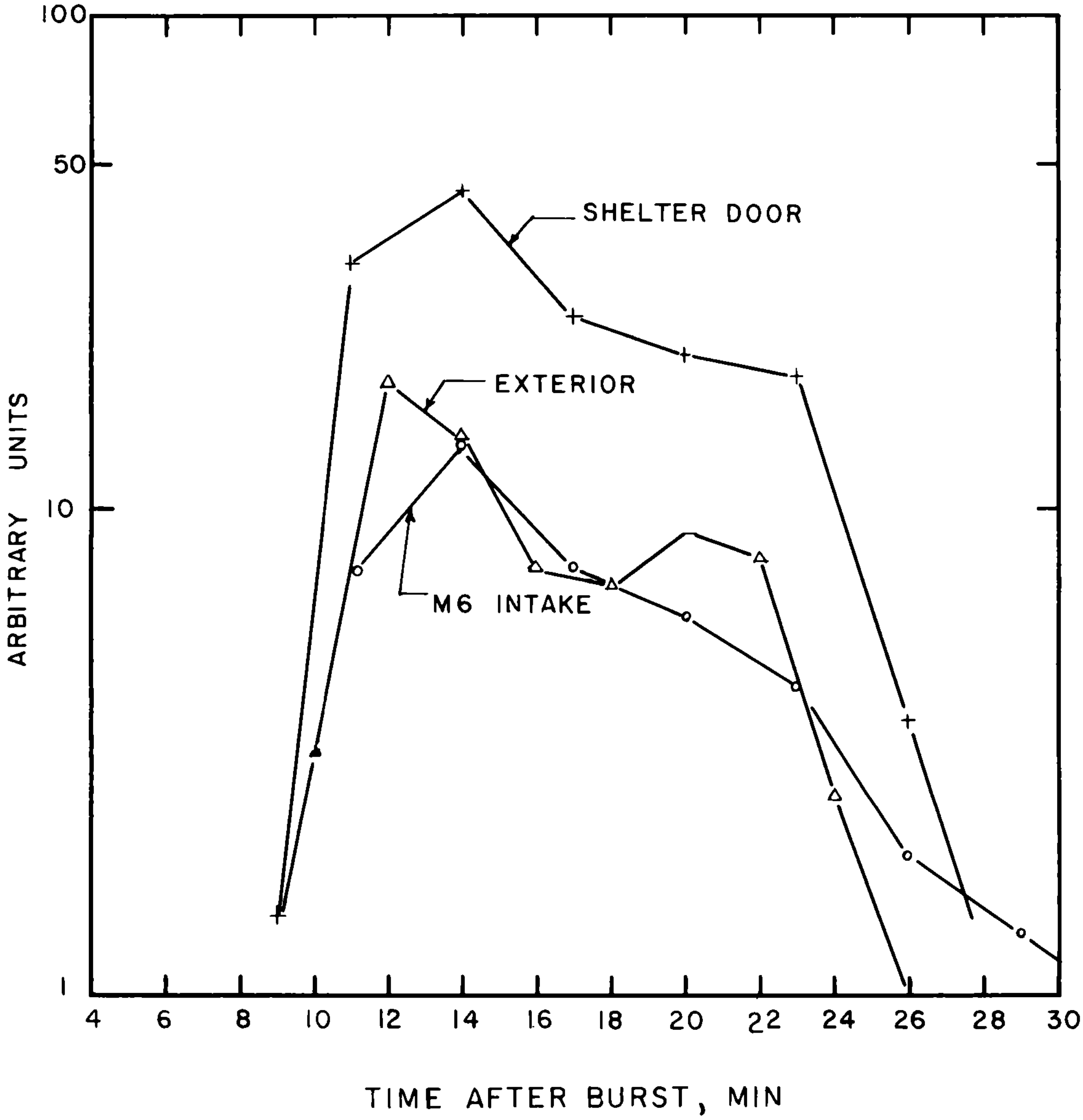


Fig. 3.4—Comparison of air sampling data, shot Diablo.

Table 3.6--INTERIOR DOSE DATA, SHOT DIABLO

Center Ventilator

Location (Fig. 2.11)	Height, ft	Initial Gamma Dose, mr[a] 1	2	3	Fallout Gamma Dose, mr[b] 1	2	3
C4	12	200+	190	180	110	110	95
C4	9	70	60	70	25	35	30
C4	6	30	30	20	12	10	10
C4	3	10	20	20	10	17	22

a - exposed from H to H+5 min. b - exposed from H+5 to H+76 min.

Rear Ventilator

Location (Fig. 2.11)	Height, ft	Initial Gamma Dose, mr[c] 1	2	3	Fallout Gamma Dose, mr[d] 1	2	3
C7	12	30	30	20	20	20	23
C7	9	10	10	10	8	20	11
C7	6	0	10	10	8	6	5
C7	3	3	7	4	0	5	5

c - exposed from H to H+4 1/2 min. d - exposed from H+6 to H+77 min.

Other Stations - 3-ft height

Location (Fig. 2.11)	Initial[e] Gamma Dose, mr 200 mr dosimeter	Background dosimeter	Fallout[f] Gamma Dose, mr 200 mr dosimeter	Background dosimeter
A1	4		30	10+
A4	4.5		3	4.5
A7	4		5	10+
E1	0.5		18	10+
E4	2		10	10+
E6	3.5		1	0.5

e - exposed from H to H+3 min. f - exposed from H+8 to H+76 min.

200-mr electroscope dosimeters were grouped at each height under the ventilators. The other stations had only one 200-mr dosimeter. Ten-milliroentgen background dosimeters were also exposed at these stations beginning about 3 min after burst.

Attenuation of radiation below the exhaust ventilators is indicated by the dose measurements. A comparison of doses at various distances below the vent to the dose at the vent is given in Fig. 3.5. The data show that radiation has been reduced at the 3-ft level to 10 to 20 per cent of the 12-ft level.

3.4.2 Intensity Measurements, Shot Diablo

Measurements of gamma intensity were made on top of the shelter at H+5 1/2 hr with AN/PDR-T1B survey instruments. Results are shown in Table 3.7

Table 3.7--EXTERIOR SURVEY DATA, SHOT DIABLO
(Time of survey: H+5 1/2 hr; instrument: AN/PDR-T1B)

Station (Fig. 2.13)	Intensity, r/hr
1	2.0
2	2.2
3	2.3
4	2.2
5	2.3
6	2.2
7	2.2
8	2.2
9	2.0
10	2.1
11	2.4
12	2.2
13	2.2
14	2.2
15	2.2
16	2.2
17	2.2
18	2.2

The first survey of the interior of the shelter was made after cessation of fallout during the period H+94 to H+108 min. Measurements at the various stations shown in Fig. 2.11 are given in Table 3.8.

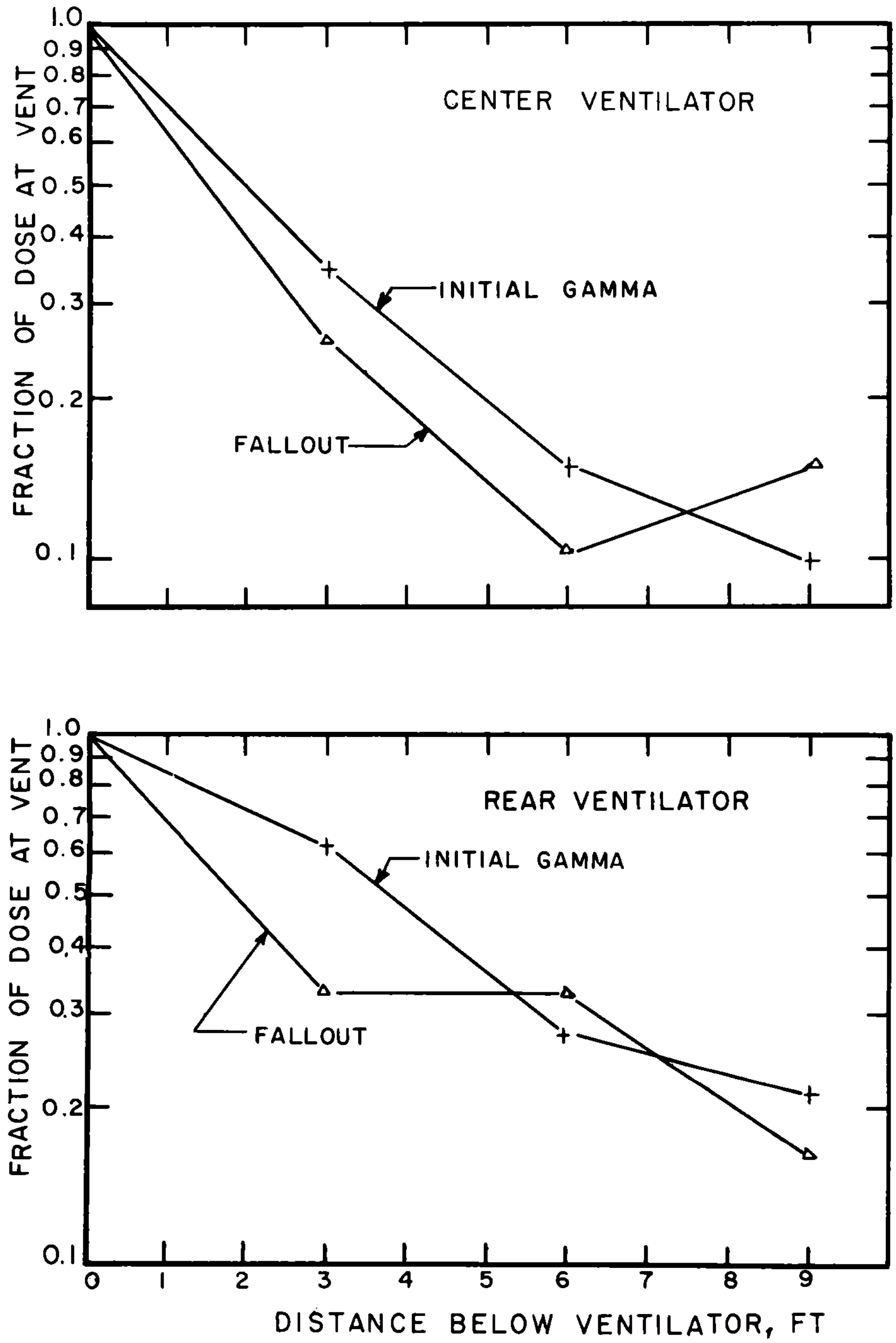


Fig. 3.5--Reduction of dose below ventilators, expressed as **fraction of dose at vent opening, shot Diablo.**

Table 3.8--INTERIOR SURVEY DATA, SHOT DIABLO

Location (Fig. 2.11)	Height, ft	First survey (H+100 min) Reading, mr/hr	First survey (H+100 min) Residual number	Second survey (H+5 1/2 hr) Reading, mr/hr	Second survey (H+5 1/2 hr) Residual number
A1	3	50	0.005	3.5	0.0018
B1	3	10	0.001	5.0	0.0026
C1	3	14	0.0014	2.3	0.0012
D1	3	10	0.001	2.4	0.0013
E1	3	5	0.0005	1.5	0.00078
E1	6	11	0.0011	1.5	0.00078
D1	3	9	0.0009	2.5	0.0013
D1	6	21	0.0021	2.2	0.0011
D1	9	11	0.0011	1.4	0.00073
C1	3	13	0.0013	2.8	0.0015
C1	6	15	0.0015	4.0	0.0021
C1	9	8	0.0008	1.8	0.00094
C1	12	2	0.0002	0.7	0.00036
B1	3	11	0.0011	3.5	0.0018
B1	6	13	0.0013	3.0	0.0016
B1	9	5	0.0005	0.9	0.00047
A1	3	32	0.0032	5.0	0.0026
A1	6	36	0.0036	4.7	0.0024
A2	3	6	0.0006	1.5	0.00078
B2	3	5	0.0005	0.9	0.00047
C2	3	3.5	0.00035	1.0	0.00052
D2	3	3	0.0003	1.0	0.00052
E2	3	3.5	0.00035	0.7	0.00036
E2	6	-	-	0.4	0.00021
D2	3	4.3	0.00043	0.8	0.00042
D2	6	3.2	0.00032	0.8	0.00042
D2	9	2.6	0.00026	0.6	0.00031
C2	3	3.4	0.00034	0.9	0.00047
C2	6	3.3	0.00033	0.8	0.00042
C2	9	2.1	0.00021	0.4	0.00021
C2	12	1.1	0.00011	0.3	0.00016
B2	3	4.3	0.00043	0.7	0.00037
B2	6	3.4	0.00034	0.4	0.00021
B2	9	1.3	0.00013	0.4	0.00021
A2	3	13	0.0013	1.7	0.00088
A2	6	4	0.0004	1.4	0.00073
A3	3	1.5	0.00015	0.30	0.00016
B3	3	1.3	0.00013	0.25	0.00013
C3	3	1.1	0.00011	0.17	0.000089
D3	3	0.7	0.00007	0.10	0.000052
E3	3	0.4	0.00004	0.07	0.000036
E3	6	0.5	0.00005	0.10	0.000052

Table 3.8 (Continued)

Location (Fig. 2.11)	Height, ft	First survey Reading, mr/hr	First survey Residual number	Second survey Reading, mr/hr	Second survey Residual number
D3	3	0.7	0.00007	0.12	0.000062
D3	6	0.6	0.00006	0.09	0.000047
D3	9	0.3	0.00003	0.11	0.000057
C3	3	1.2	0.00012	0.15	0.000078
C3	6	1.2	0.00012	0.16	0.000083
C3	9	1.1	0.00011	0.14	0.000073
C3	12	1.1	0.00011	0.20	0.00010
B3	3	1.4	0.00014	0.25	0.00013
B3	6	1.1	0.00011	0.22	0.00011
B3	9	0.8	0.00008	0.19	0.000078
A3	3	1.3	0.00013	0.27	0.00014
A3	6	0.8	0.00008	0.25	0.00013
A4	3	0.2	0.00002	0.09	0.000047
B4	3	0.4	0.00004	0.15	0.000078
C4	3	1.6	0.00016	0.17	0.000088
D4	3	0.8	0.00008	0.17	0.000088
E4	3	0.4	0.00004	0.10	0.000052
E4	6	0.4	0.00004	0.09	0.000047
D4	3	0.7	0.00007	0.13	0.000068
D4	6	0.8	0.00008	0.13	0.000068
D4	9	0.6	0.00006	0.11	0.000057
C4	3	1.4	0.00014	0.18	0.000094
C4	6	1.4	0.00014	0.20	0.00010
C4	9	4.1	0.00041	0.21	0.00011
C4	12	30	0.003	2.0	0.0010
B4	3	0.3	0.00004	0.14	0.000073
B4	6	0.4	0.00004	0.16	0.000083
B4	9	0.4	0.00004	0.14	0.000073
A4	3	0.2	0.00002	0.09	0.000047
A4	6	0.2	0.00002	0.11	0.000057
A5	3	0.2	0.00002	0.15	0.000078
B5	3	0.5	0.00005	0.18	0.000094
C5	3	1.0	0.0001	0.25	0.00013
D5	3	0.5	0.00005	0.17	0.000088
E5	3	0.5	0.00005	0.13	0.000068
E5	6	0.2	0.00002	0.09	0.000047
D5	3	0.5	0.00005	0.15	0.000078
D5	6	0.5	0.00005	0.12	0.000062
D5	9	0.5	0.00005	0.13	0.000068
C5	3	1.0	0.0001	0.18	0.000094
C5	6	1.3	0.00013	0.20	0.00010
C5	9	1.4	0.00014	0.23	0.00012

Table 3.8 (Continued)

Location (Fig. 2.11)	Height, ft	First survey Reading, mr/hr	First survey Residual number	Second survey Reading, mr/hr	Second survey Residual number
C5	12	1.5	0.00015	0.21	0.00011
B5	3	0.6	0.00006	0.17	0.000088
B5	6	0.5	0.00005	0.12	0.000062
B5	9	0.4	0.00004	0.10	0.000052
A5	3	0.2	0.00002	0.12	0.000062
A5	6	0.2	0.00002	0.10	0.000052
A6	3	0.2	0.00002	*	-
B6	3	0.3	0.00003	*	-
C6	3	1.5	0.00015	*	-
D6	3	0.5	0.00005	*	-
E6	3	0.3	0.00003	*	-
E6	6	0.5	0.00005	0.15	0.000078
D6	3	0.5	0.00005	0.15	0.000078
D6	6	0.4	0.00004	0.17	0.000088
D6	9	0.4	0.00004	0.15	0.000078
C6	3	0.7	0.00007	0.20	0.00010
C6	6	1.0	0.0001	0.25	0.00013
C6	9	1.6	0.00016	0.27	0.00015
C6	12	2.7	0.00027	0.30	0.00016
B6	3	0.4	0.00004	0.15	0.000078
B6	6	0.5	0.00005	0.10	0.000052
B6	9	0.4	0.00004	0.10	0.000052
A6	3	0.3	0.00003	0.09	0.000047
A6	6	0.3	0.00003	0.11	0.000057
A7	3	0.1	0.00001	0.05	0.000026
B7	3	0.3	0.00003	0.08	0.000042
C7	3	1.0	0.0001	0.13	0.000068
D7	3	0.5	0.00005	0.08	0.000042
E7	3	0.2	0.00002	0.04	0.000021
E7	6	0.2	0.00002	0.05	0.000026
D7	3	0.4	0.00004	0.10	0.000052
D7	6	0.5	0.00005	0.09	0.000047
D7	9	0.5	0.00005	0.07	0.00036
C7	3	0.6	0.00006	0.11	0.000057
C7	6	0.7	0.00007	0.14	0.000074
C7	9	1.1	0.00011	0.17	0.000088
C7	12	2.0	0.0002	0.20	0.00010
B7	3	0.4	0.00004	0.07	0.000036
B7	6	0.6	0.00006	0.05	0.000026
B7	9	0.3	0.00003	0.07	0.000036
A7	3	0.1	0.00001	0.06	0.000031
A7	6	0.4	0.00004	0.07	0.000036

Residual numbers for each station were obtained by correcting the exterior measurements to H+100 min using the observed decay rate on the GITR.

Residual-number contours were developed from the data in Table 3.8. Figure 3.6 shows contours on horizontal plane sections at 3, 6, and 9 ft above the shelter floor, on a vertical section through the center line of the shelter, and on a vertical section through grid column 4.

Residual numbers given in Table 3.8 and contours in Fig. 3.6 show that almost all the shelter gave residual numbers better than 0.001; most of the shelter gave residual numbers approaching 0.00001. Restricted areas near the entrance and within about 1 ft of the center vent gave residual numbers poorer than 0.001.

Attenuation of radiation below the vents was determined from the data in Table 3.8; results are plotted in Fig 3.7. Attenuation is essentially proportional to the distance from the vent down to 6 ft from the floor. This rate is substantially greater than the attenuation based on dose measurements (Fig. 3.5).

A second interior survey, made after sandbagging the center vent, gave the results shown in Table 3.8. Shielding the vent did not result in appreciable improvement of residual numbers in most parts of the shelter. However, a three-fold reduction was noted directly below the vent. Observable reductions also were noted at stations C3, C4, and C5. Residual numbers given in Table 3.8 for the second survey were obtained by correcting the interior readings to H+100 minutes using the GITR decay curve and then comparing the interior readings to the exterior readings corrected to the same time.

Additional intensity measurements were taken in the shelter by five AN/PDR-27c low-range radiacs whose signals were recorded on Brown recorders. The traces of these instruments for the first 2 hr are shown in Fig. 3.8, together with the interior survey measurements made at the same locations. The data are in fair agreement, the interior survey measurements tending to be somewhat higher than the recorded data.

3.4.3 Directional Gamma Measurements, Shot Diablo

Data obtained by the directional gamma instrument are plotted in Figs. 3.9 through 3.12. The instrument records have been corrected to 1 hr after burst. The unit of measurement is in milliroentgens per hour per 10 degrees of solid angle. When properly summed over 4 pi, the result of the directional survey should equal the measured intensity at the point of interest. Figure 3.9 shows the result of a transverse rotation of the instrument in a plane including the shelter door.

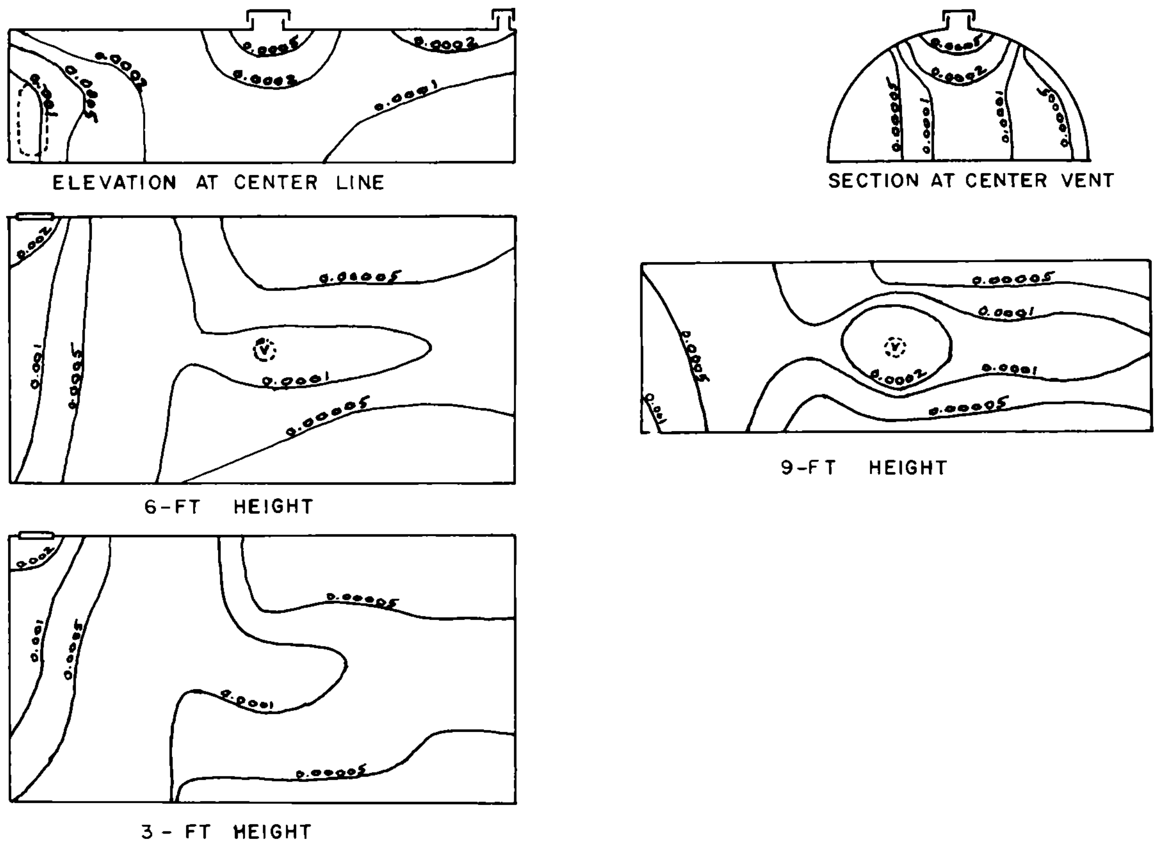


Fig. 3.6--Residual number contours for first interior survey, shot Diablo.

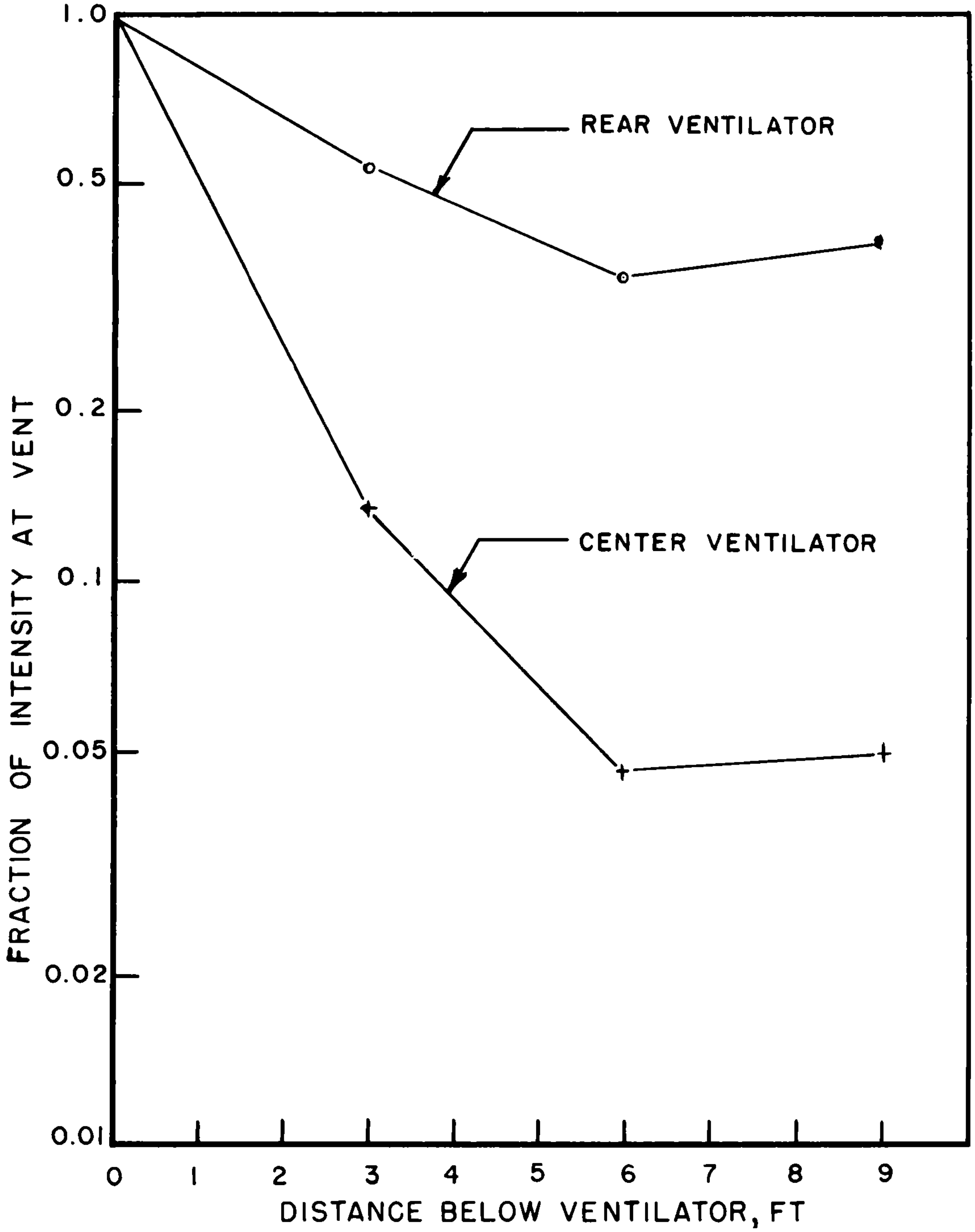


Fig. 3.7--Reduction of intensity below ventilators, expressed as fraction of intensity at vent opening, shot Diablo.

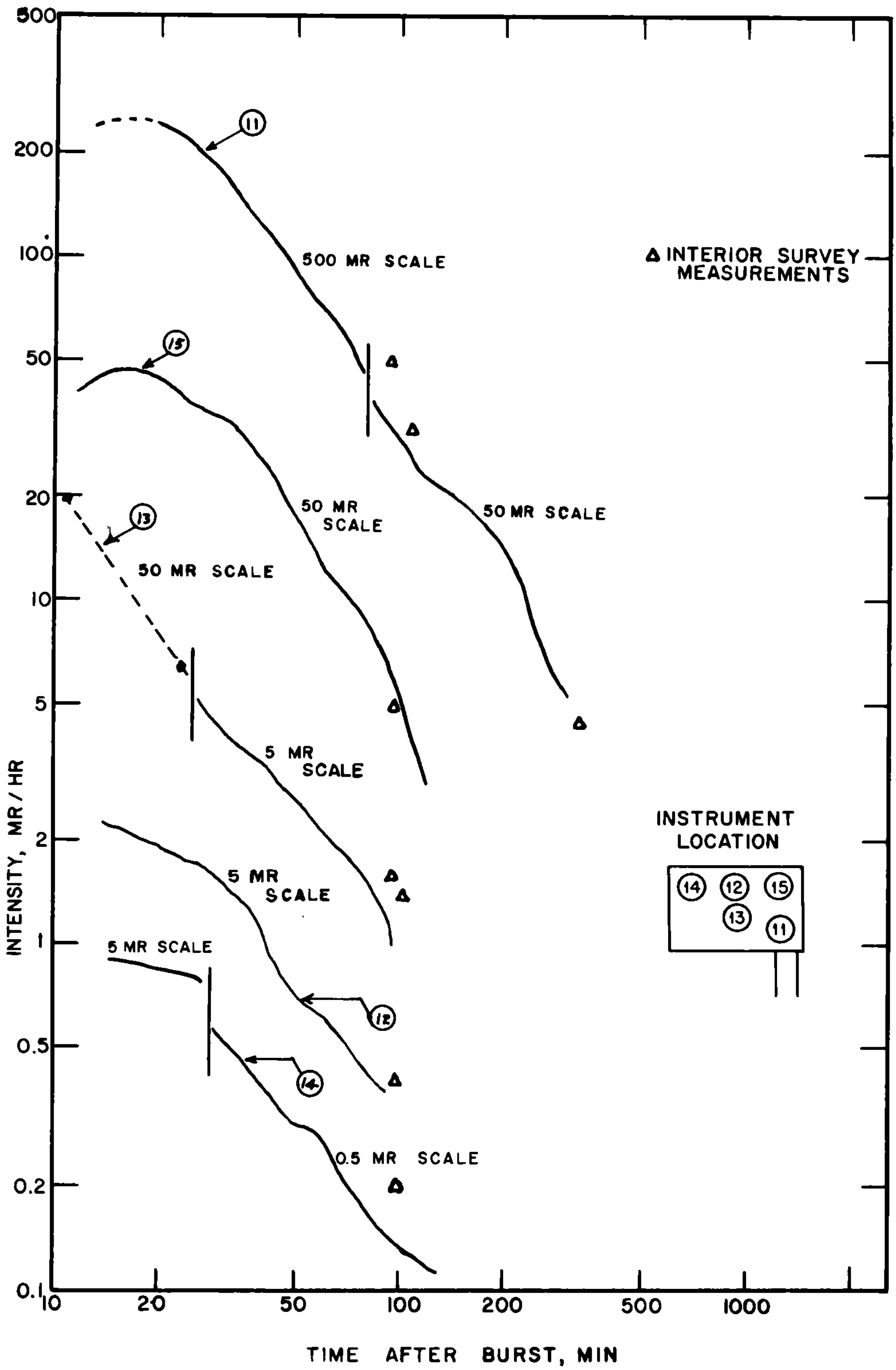


Fig. 3.8—Results from fixed AN/PDR-27c instruments in shelter, shot Diablo.

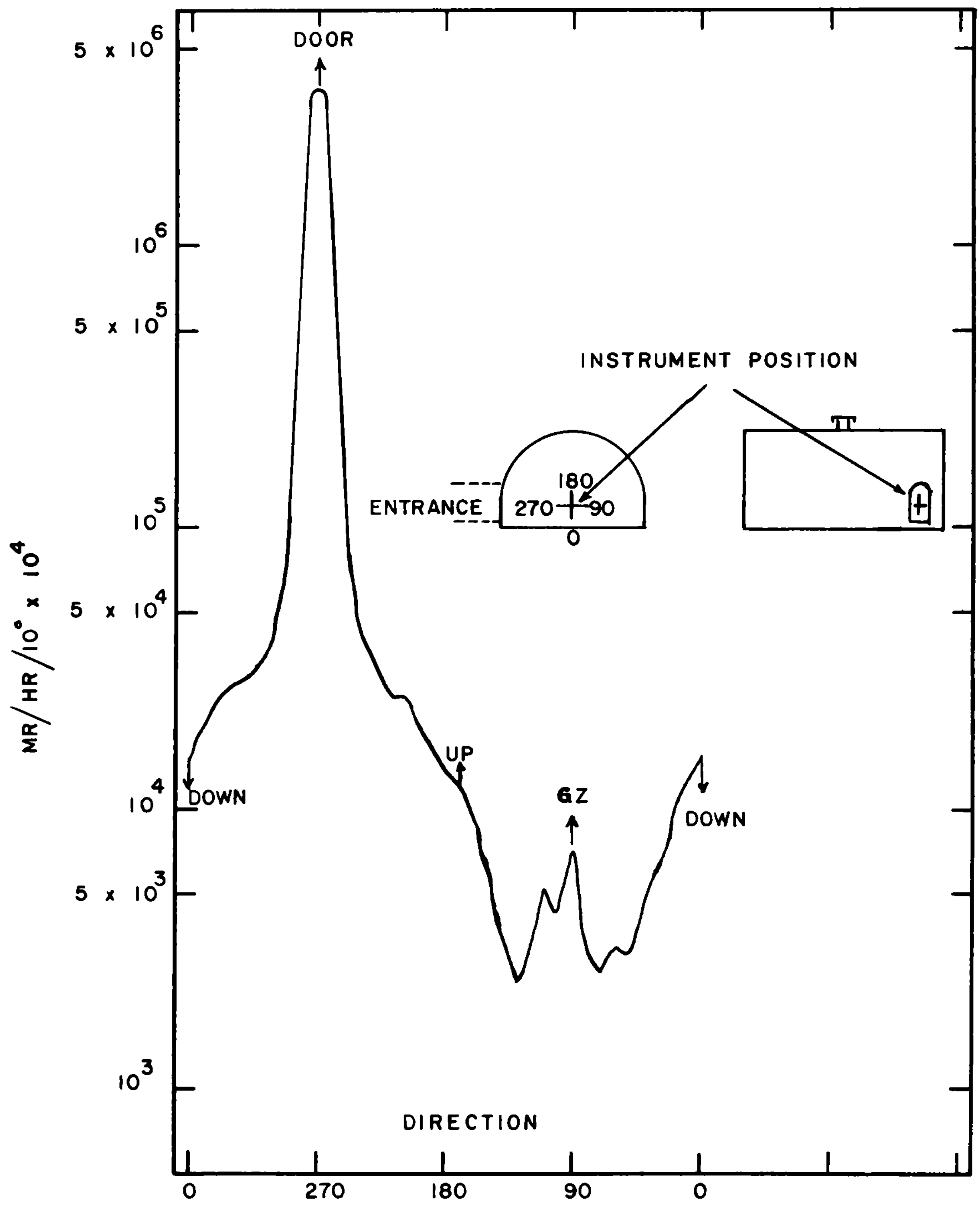


Fig. 3.9—Directional characteristics of gamma radiation flux on center line of shelter opposite door, shot Diablo.

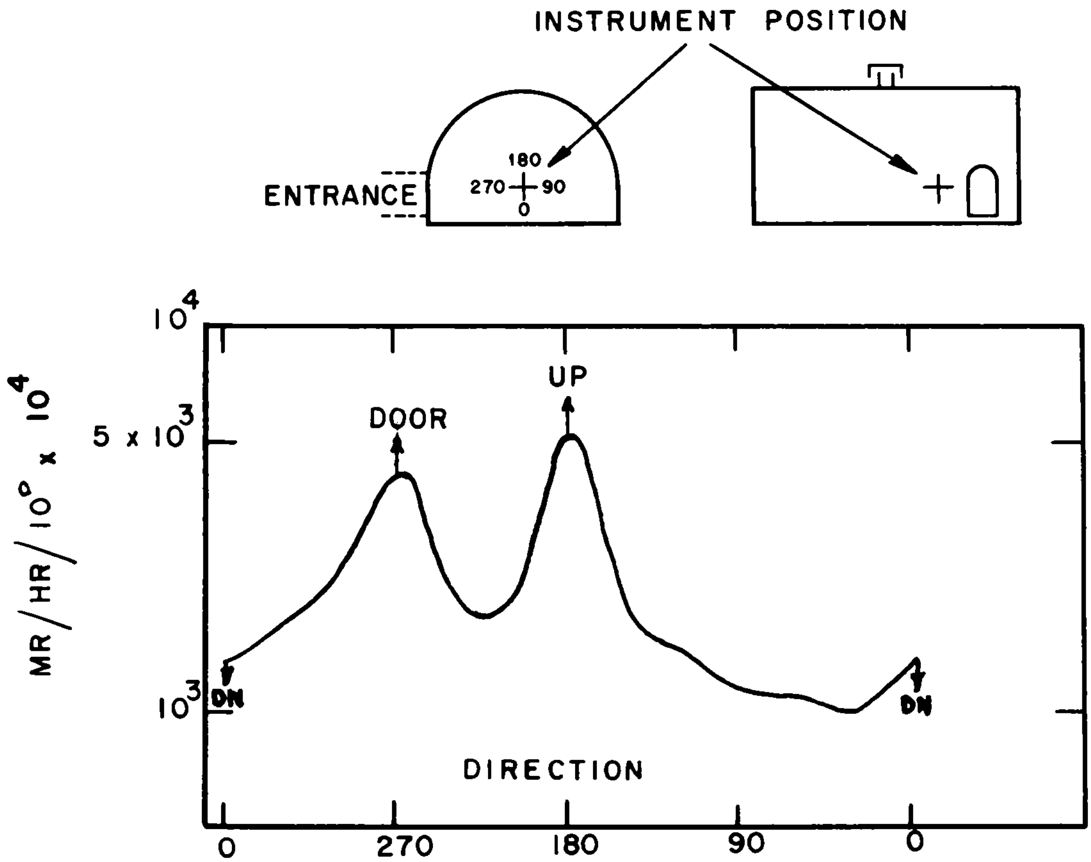


Fig. 3.10—Directional characteristics of gamma radiation flux on transverse plane midway between door and center ventilator, shot Diablo.

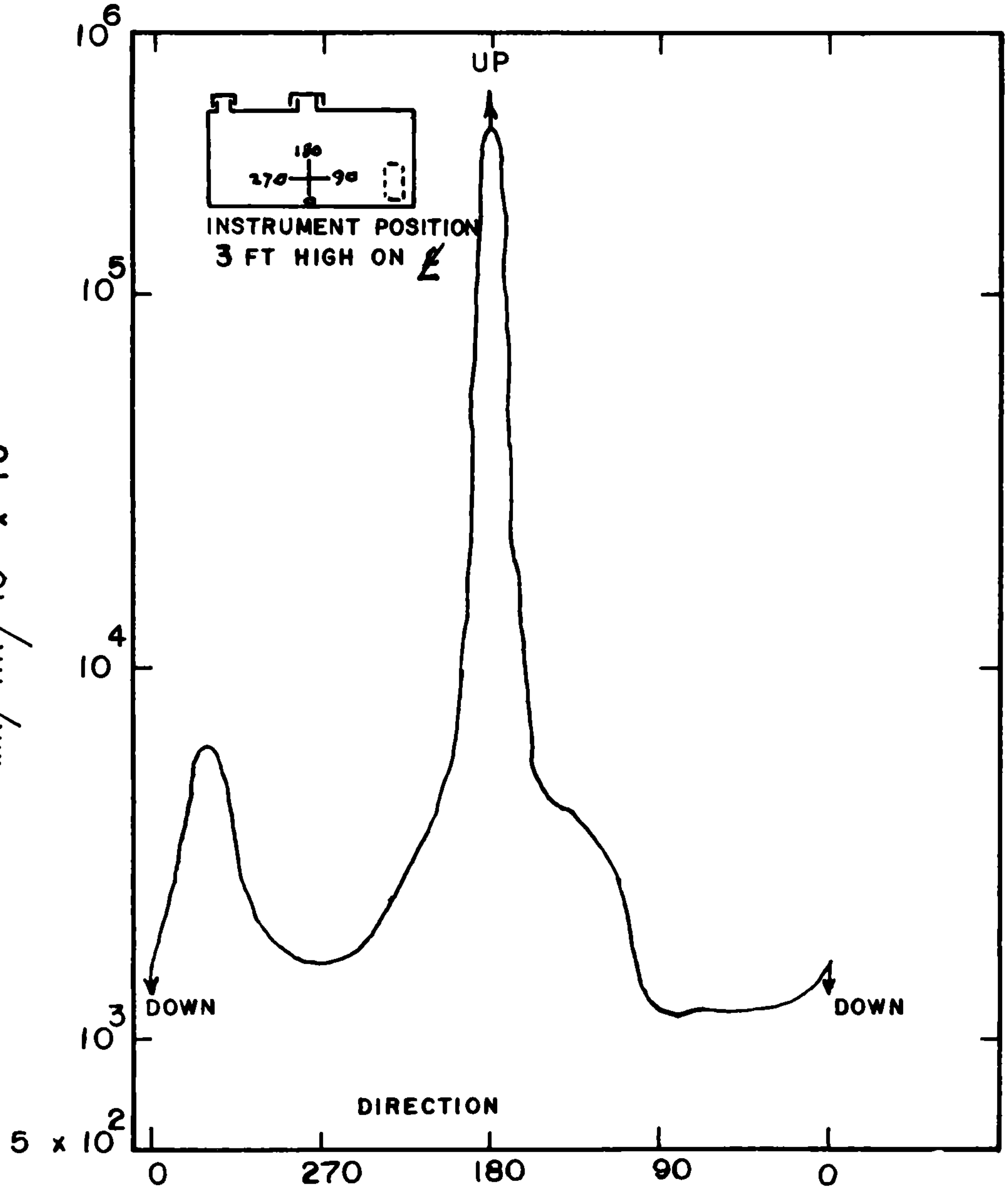


Fig. 3.11--Directional characteristics of gamma radiation flux along shelter axis under center ventilator, shot Diablo.

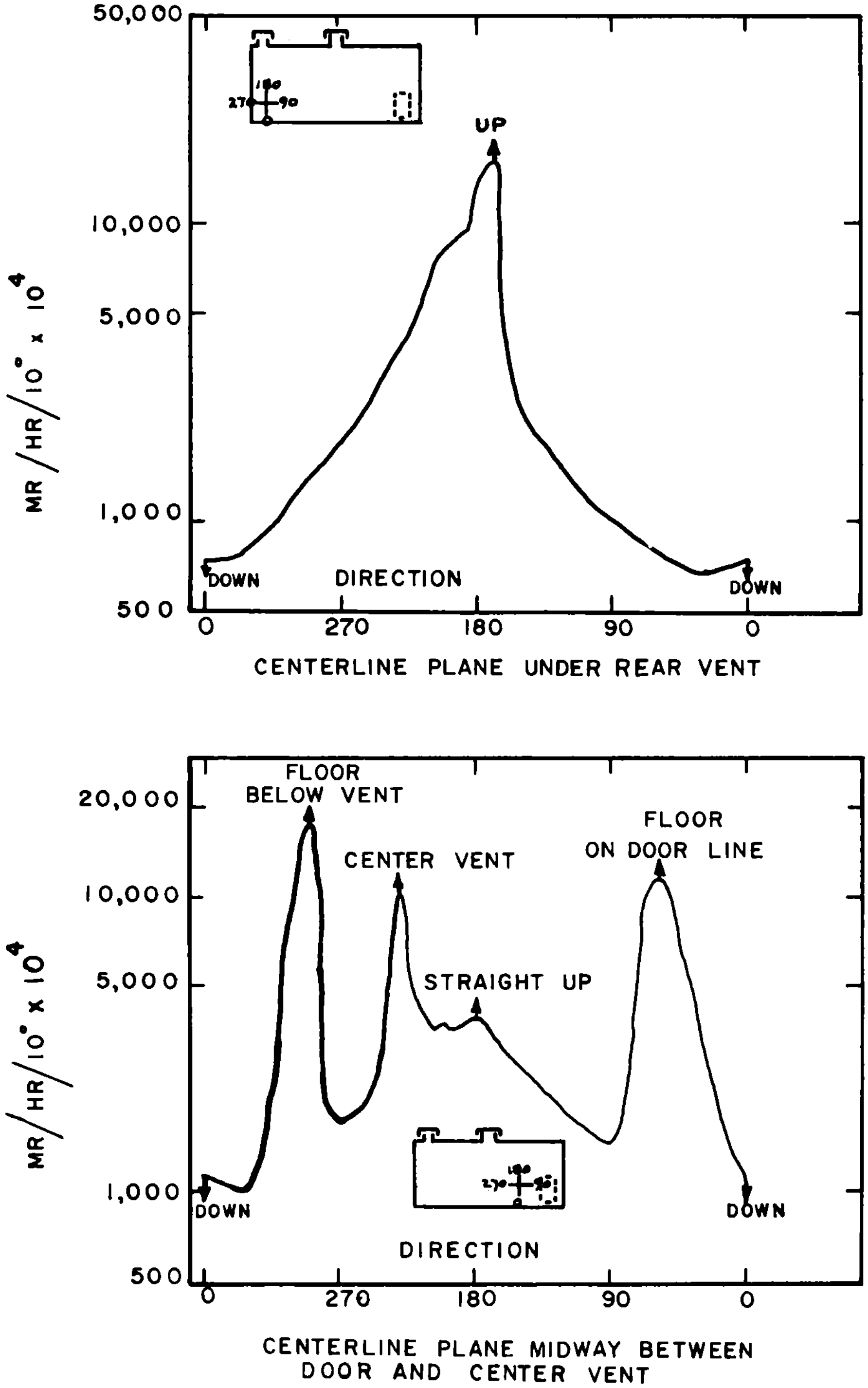


Fig. 3.12--Directional characteristics of gamma radiation flux along shelter axis at two points of measurement, shot Diablo.

Figure 3.10 gives the results of a transverse rotation midway between the door and the center ventilator, showing the greatly reduced contribution from the door. Figure 3.11 is a longitudinal rotation approximately under the center ventilator, and Fig. 3.12 shows two longitudinal rotations, one under the rear ventilator and one midway between the door and center ventilator.

3.4.4 Energy-spectrum Measurements, Shot Diablo

Spectral data taken in the shelter has not been reduced at this date.

3.5 SUPPORTING TECHNICAL STUDIES

A large amount of supporting data were obtained on shot Diablo, most of which has not yet been reduced. Some information is available on the nature of the fallout event and the resulting radiation field. Figure 3.13 gives a comparison of the planning decay curve, the intensity-time record from the GITR on the shelter roof, and the average decay of fallout samples measured in the 4-pi ion chamber. The GITR record indicates fallout arrival at about H+7 min and peak intensity at about H+15 min.

Measurements from one of the AN/PDR-27c instruments attached to a Brown recorder and the directional gamma instrument also were used to determine time of arrival. The AN/PDR-27c was in a particularly good position to observe the radiation beam through the entrance tunnel. The record from this instrument, given in Fig. 3.14, shows a sharp rise at about H+6 min. Figure 3.15 gives the record of the directional gamma instrument, which was pointed directly upward at shot time.

Table 3.9 gives measurements of the incremental fallout collector trays at USNRDL. Time of arrival is during the sixth minute after burst. The variability shown between successive trays is a statistical one due to the small tray size. The activity was found to be included mainly in large glassy fallout particles of high specific activity. Nevertheless, the resulting radiation field at the shelter was remarkably uniform, with practically no gradient. Figure 3.16 shows the directional properties of the radiation field as measured by the directional gamma instrument at a point on the shelter roof. Arbitrary units are used in these curves. Prominent "bumps" in the sectors where the instrument was pointed toward the ground are evidence of small areas (particles) of high activity.

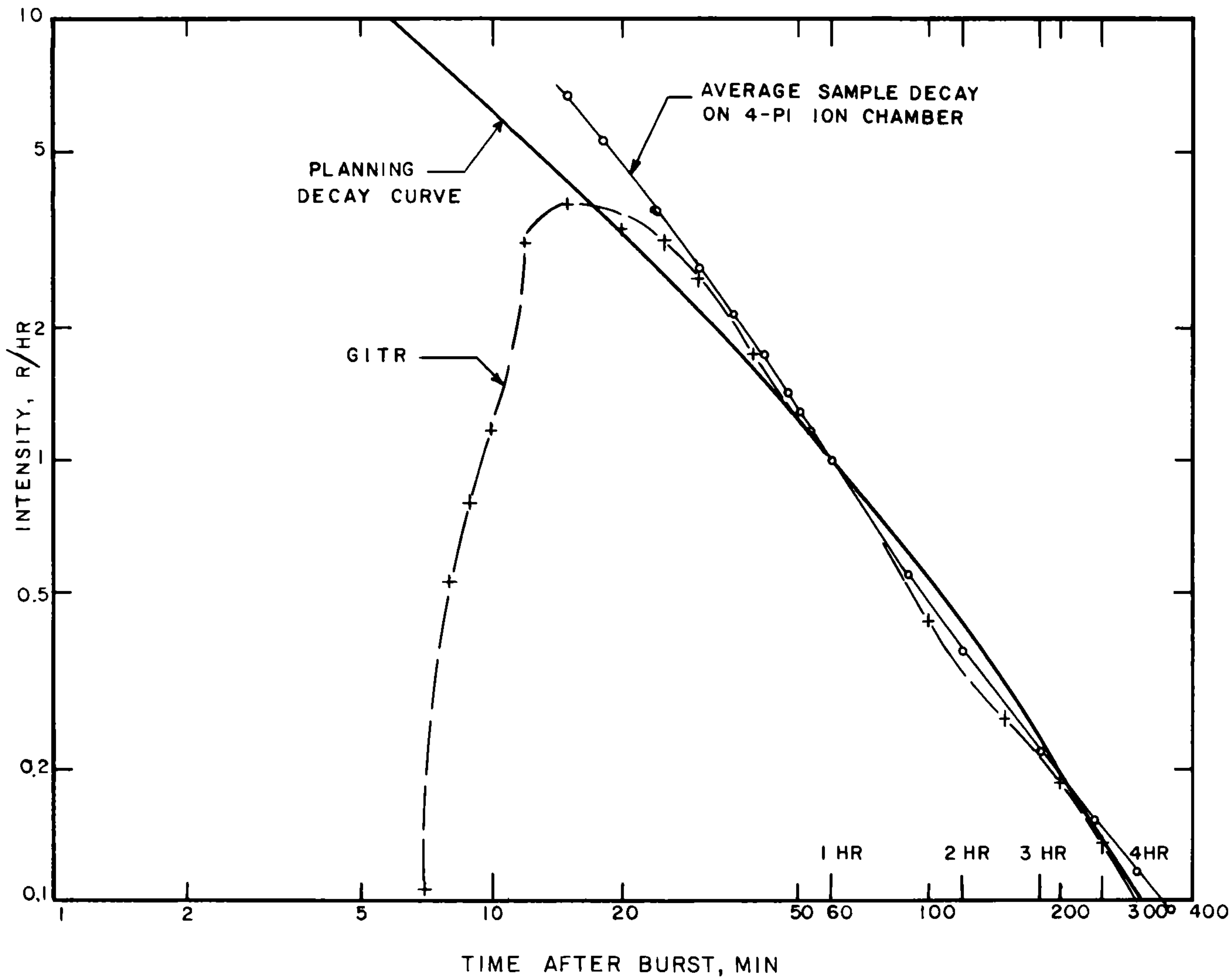


Fig. 3.13--Early decay measurements on shot Diablo, normalized to unit standard intensity.

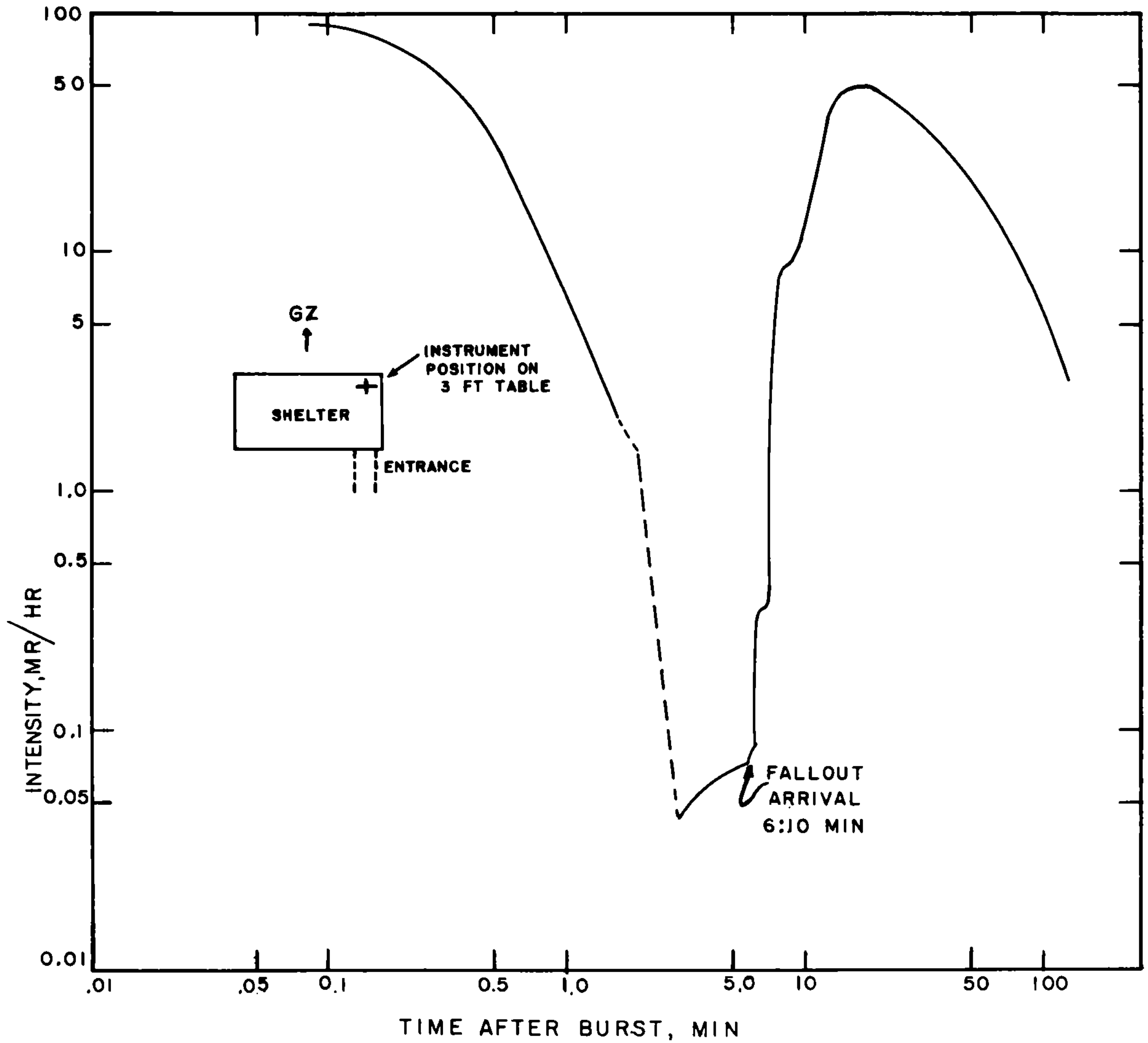


Fig. 3.14--Early intensity-time record on fixed AN/PDR-27c, shot Diablo.

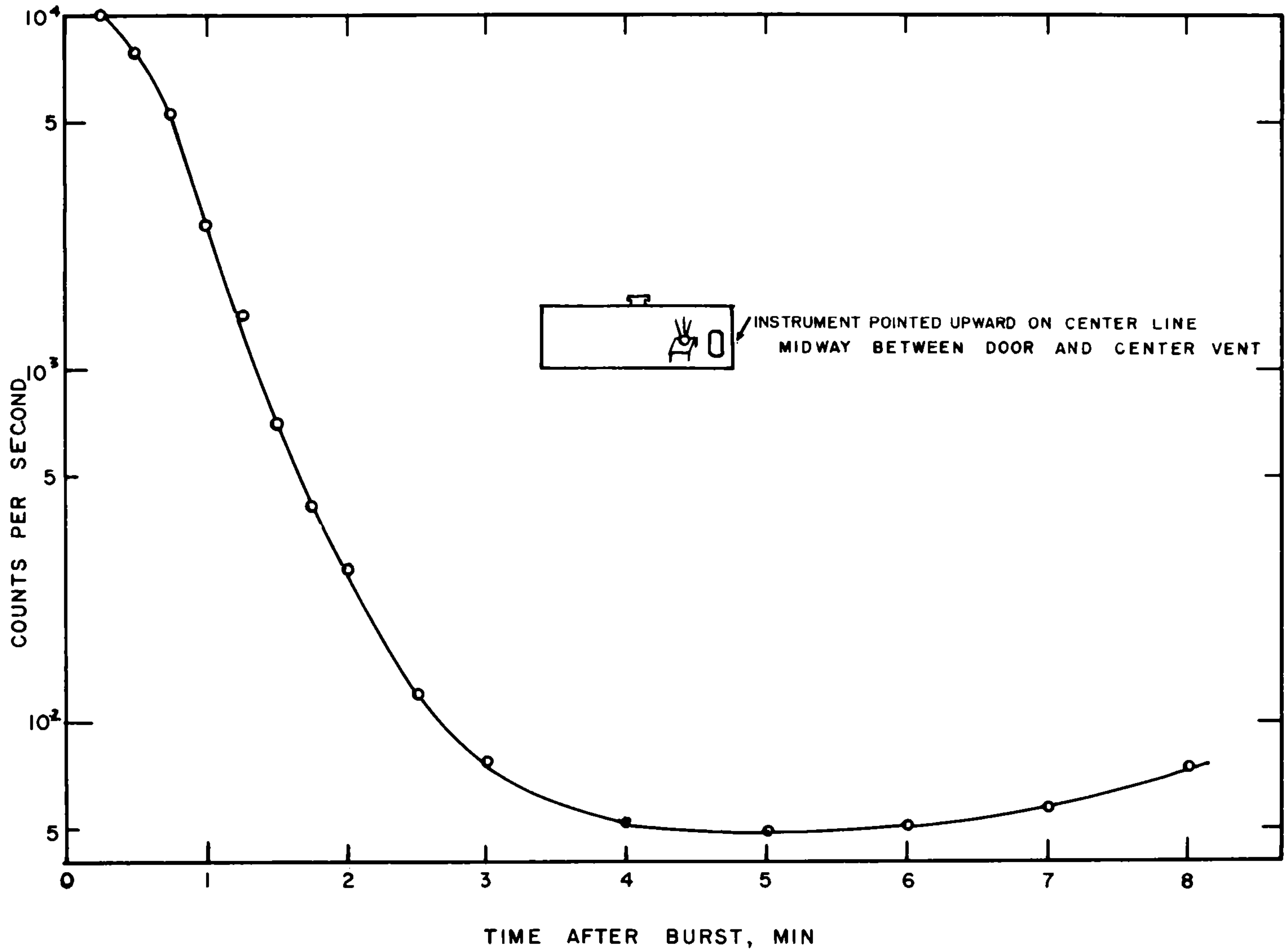


Fig. 3.15--Early intensity-time record on directional gamma instrument, shot Diablo.

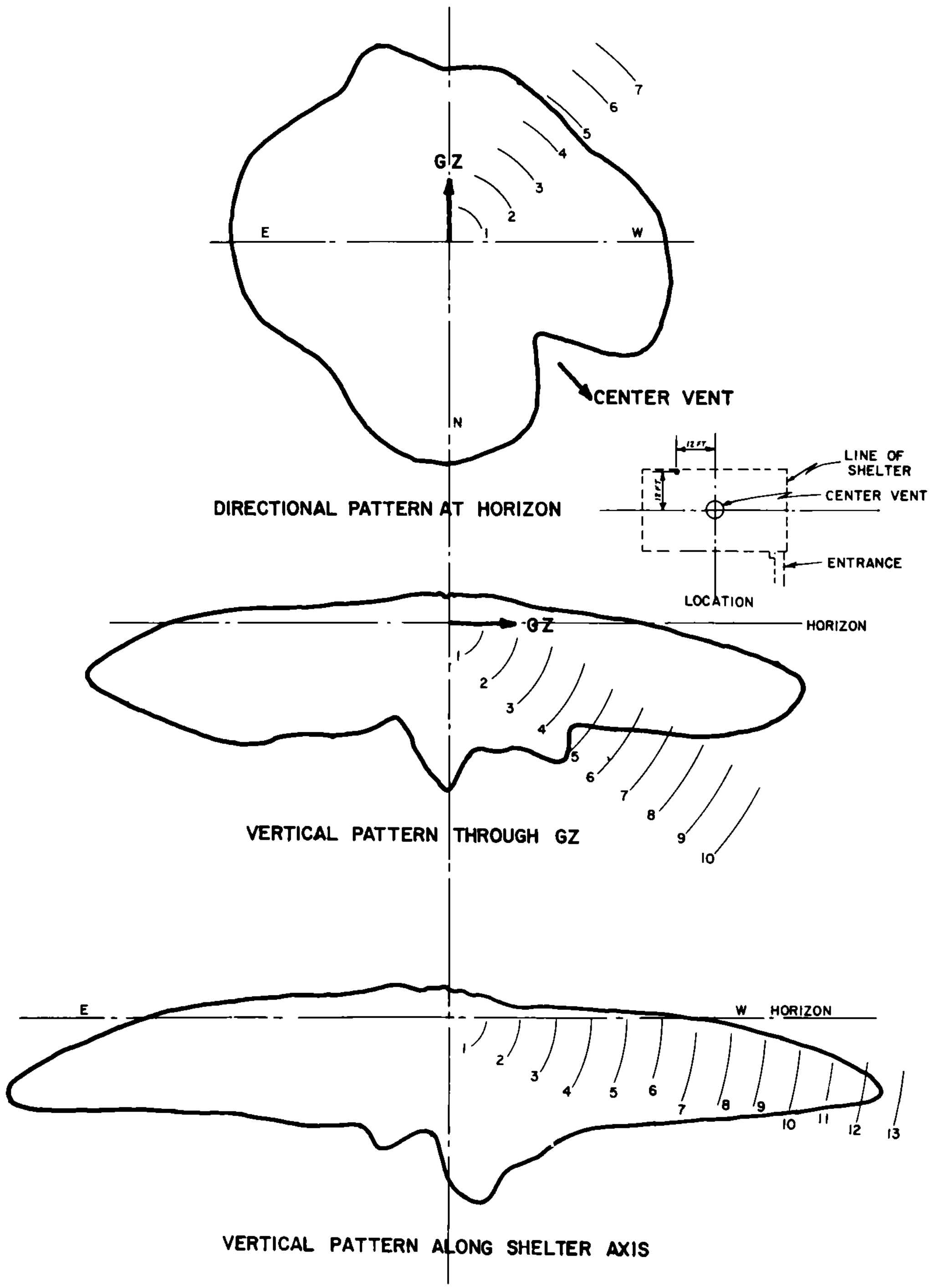


Fig. 3.16--Directional characteristics of radiation field on top of the shelter, shot Diablo.

Table 3.9—INCREMENTAL COLLECTOR DATA

Tray	Time, min	Activity*, counts/min	Cumulative activity, counts/min
515	- 1:30	23	23
516	- 0:30	3	26
517	0:30	-	26
518	1:30	13	39
519	2:30	17	56
520	3:30	14	70
521	4:30	-	70
522	5:30	97	167
523	6:30	1,026,000	1,026,167
524	7:30	47	1,026,214
525	8:30	1,671,000	2,697,214
526	9:30	1,117,000	3,814,214
527	10:30	1,688,000	5,502,214
528	11:30	488,900	5,991,114
529	12:30	163	5,991,277
530	13:30	1,208,000	7,199,277
531	14:30	117	7,199,394
532	15:30	938,800	8,138,194
533	16:30	541,000	8,679,194
534	17:30	97	8,679,291
535	18:30	434,600	9,113,891
536	19:30	60	9,113,951
537	20:30	70	9,114,021
538	21:30	33	9,114,054
539	22:30	168,000	9,282,054
540	23:30	308,900	9,590,954
541	24:30	393	9,591,347
542	25:30	383,400	9,974,747
543	26:30	518,300	10,493,047
544	27:30	27	10,493,047
545	28:30	0	10,493,047

* Counts per minute on gamma scintillation counter. Samples counted on July 16, 1957, and corrected for decay to 1200 on that day.

3.6 INITIAL MONITORING FROM SHELTER

Because of the high intensities resulting from shot Diablo, initial monitoring from the shelter was delayed until 7 hr after burst. Measurements were made at Areas 1 and 3 (Fig. 2.1); telemeter data showed that Area 2 had not received significant fallout. The single-point (center) reading on Area 3 was 6 r/hr. The gradient was very flat, the lowest reading being 5 r/hr and the highest reading 7 r/hr. The single-point reading was sufficient for decision purposes at the shelter. The single-point reading in Area 1 at H+7 hr was 3 r/hr. The gradient was also flat; the single-point was a sufficient measure of the situation.

3.7 STAGING-AREA RECLAMATION AND TEST METHODS

The center area, Area 1, was selected for phase II operations. Because of the high intensity resulting from shot Diablo, these operations were conducted on D+2 days when the intensity in the area was about 300 mr/hr. The residual number in the center of the area after one complete pass of the equipment was about 0.16. A second pass over the central 100- by 100-ft area reduced the residual number to 0.11. Working conditions for the second pass were very poor; large numbers of rocks were turned up by the grader. Further attempts to lower the residual number by locating spills with AN/PDR-27c instruments and by removing the spills with front-end loader and dump truck were unsuccessful.

Results of the proof test of the reclamation test methods are given in Tables 3.10 and 3.11. Table 3.10 gives the actual readings made near the center of the area during the process of successive enlargement of the square. Table 3.11 gives the resulting ratios obtained from these readings. These data are plotted in Fig. 3.17 according to the vertical method of predicting residual number. The measured value for the 500- by 500-ft area has been introduced as the criterion of successful prediction. Figure 3.18 gives the result of applying the horizontal method of prediction. The measured value for the 500- by 500-ft area has been introduced as a criterion of successful prediction.

Operational-dose data were obtained for the grader and scraper operators. The dose measured on self-reading dosimeters over an operating period of approximately 3 hr was 175 mr. The equivalent free-field dose during this period was 820 mr. Therefore, the residual number for this operation (because of equipment shielding and the effect of the reclaimed part of the area) was 0.21.

3.8 ALTERNATE BUFFER-ZONE TECHNIQUE

The test of a barrier as a substitute for a buffer zone was first accomplished in Area 3 on D+4 days. A barrier having an average height of 3 ft was constructed around a 100- by 100-ft cleared area. Results

Table 3.10—DATA TAKEN FOR PROOF OF TEST METHODS

(a) Uncleared Area

Ht. of Reading	Center				Two paces			
	N	E	S	W	N	E	S	W
3 ft	280	270	290	290	280	280	290	290
2 ft	280	290	310	310	290	300	310	310
1 ft	300	300	310	310	290	300	320	320

(b) After 40' by 40' clearing

Ht. of Reading	Center				Two paces			
	N	E	S	W	N	E	S	W
3 ft	100	90	100	100	110	120	100	130
2 ft	80	80	90	90	100	100	90	120
1 ft	70	70	80	80	80	80	70	110

(c) After 60' by 60' clearing

Ht. of Reading	Center				Two paces			
	N	E	S	W	N	E	S	W
3 ft	80	80	80	80	90	100	100	80
2 ft	70	70	70	70	80	90	80	70
1 ft	60	60	60	60	70	70	70	50

(d) After 100' by 100' clearing

Ht. of Reading	Center				Two paces			
	N	E	S	W	N	E	S	W
3 ft	60	60	60	70	70	80	70	60
2 ft	60	60	60	60	60	70	60	50
1 ft	60	50	50	50	60	60	60	50

Table 3.11--RATIOS FOR PROOF OF TEST METHODS
($1-R_2/R_1$, in parentheses)

(a) 40' Clearing

Height of Reading	Center Average	Two Paces N	E	S	W	Grand Average
3 ft	0.345 (0.655)	0.393 (0.607)	0.429 (0.571)	0.448 (0.552)	0.345 (0.655)	0.392 (0.608)
2 ft	0.286 (0.714)	0.345 (0.655)	0.333 (0.667)	0.387 (0.613)	0.240 (0.710)	0.329 (0.671)
1 ft	0.246 (0.754)	0.276 (0.724)	0.267 (0.733)	0.344 (0.656)	0.219 (0.781)	0.270 (0.730)

(b) 60' Clearing

Height of Reading	Center Average	Two Paces N	E	S	W	Grand Average
3 ft	0.283 (0.717)	0.322 (0.678)	0.357 (0.643)	0.345 (0.655)	0.276 (0.724)	0.316 (0.684)
2 ft	0.235 (0.765)	0.276 (0.724)	0.300 (0.700)	0.258 (0.742)	0.226 (0.774)	0.259 (0.741)
1 ft	0.197 (0.803)	0.242 (0.758)	0.234 (0.766)	0.218 (0.782)	0.156 (0.844)	0.208 (0.792)

(c) 100' Clearing

Height of Reading	Center Average	Two Paces N	E	S	W	Grand Average
3 ft	0.221 (0.779)	0.250 (0.750)	0.286 (0.714)	0.241 (0.759)	0.207 (0.793)	0.242 (0.758)
2 ft	0.202 (0.798)	0.207 (0.793)	0.234 (0.766)	0.194 (0.806)	0.162 (0.838)	0.200 (0.800)
1 ft	0.172 (0.828)	0.207 (0.793)	0.200 (0.800)	0.188 (0.812)	0.156 (0.844)	0.184 (0.816)

(d) Final 500' Clearing (3 ft. reading)

	Center Average	Two Paces N	E	S	W	Grand Average
Actual Reading (mr)	44	50	35	60	40	45.2
Ratio (RN)	0.156	0.176	0.123	0.210	0.140	0.159

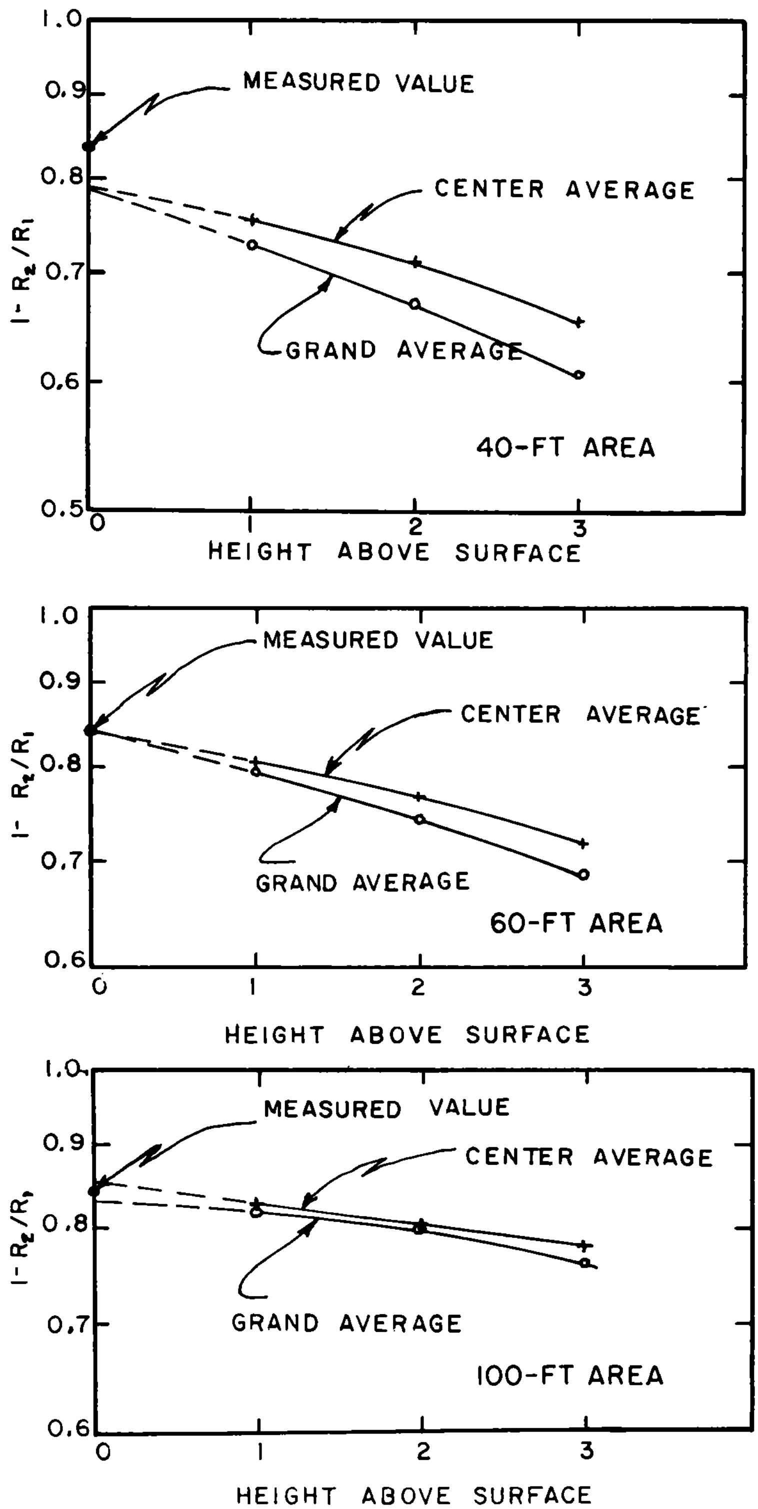


Fig. 3.17--Results of vertical method of predicting reclamation effectiveness, shot Diablo.

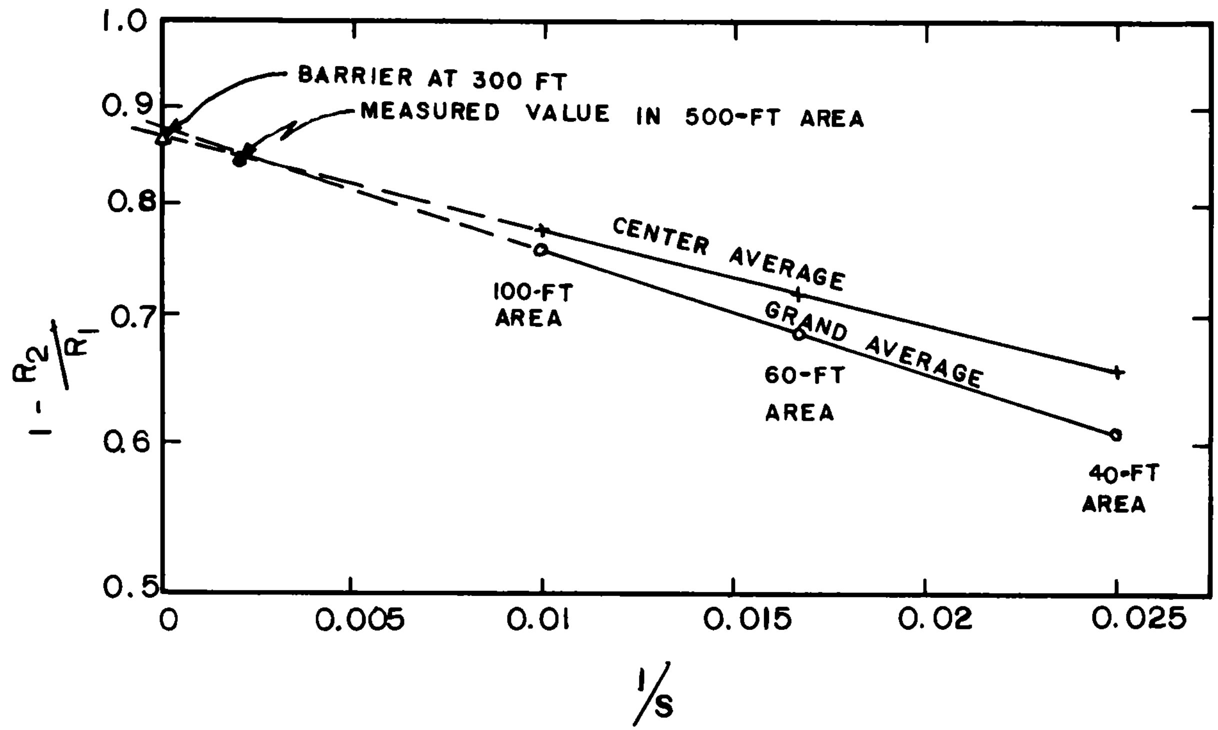


Fig. 3.18—Results of horizontal method of predicting reclamation effectiveness, shot Diablo.

are given in Table 3.12. The residual number achieved by a 500- by 500-ft cleared area (from Table 3.11) is also given. The results indicate that the 3-ft barrier is as effective as a 200-ft-wide buffer zone. The barrier required 1.3 hr of work by a D-8 dozer; therefore, the rate of operation was approximately 300 linear ft of barrier per equipment-hour.

On D+7, a barrier approximately 4 ft high was constructed around a square 300 ft on a side in the center of the 500- by 500 ft cleared area in Area 1. The residual number achieved by this effort has been introduced into Fig. 3.17. The effectiveness of the barrier appeared to be equivalent to a cleared area of infinite extent.

Table 3.12—BARRIER TEST DATA, SHOT DIABLO

(Readings at 3 ft height)

	Center					Two paces				
	N	E	S	W	Average	N	E	S	W	Average
Uncleared area	230	240	240	240	237.5	230	230	240	250	237.5
100-ft area	50	50	60	60	55	60	50	60	60	57.5
After barrier	44	45	32	32	38	44	40	30	38	38
Residual number without barrier	0.22	0.21	0.25	0.25	0.23	0.26	0.22	0.25	0.24	0.24
Residual number with barrier	0.19	0.19	0.13	0.13	0.16	0.19	0.17	0.12	0.15	0.16
Residual number in 500 ft area (Table 3.11)					0.156					0.162

Chapter 4

DISCUSSION

Although only one effective run was accomplished under conditions of full participation, project objectives were all met, with two exceptions that will be noted in the following sections. The results cannot be completely evaluated without the aid of some of the data yet to be reduced. The following discussion and resulting conclusions must therefore be regarded as tentative.

4.1 OPERATIONAL MONITOR SYSTEM

The dosimeter-tube procedure was effective in providing information on the course of the radiological event outside the shelter, despite the exaggerated readings introduced by the film-badge cup at the top of the tube (Sec. 3.2). There are some anomolies in the data for the forward tube; a constant intensity was measured for nearly 15 min at the peak, and there was a wild oscillation in the measurements at about 45 min after burst. Even these data would have provided necessary radiological information. Data for the after tube are much more stable and closely approximate the GITR information except for absolute level.

Several additional pieces of operational data were obtained from the dosimeter tubes. No significant problem was encountered concerning the contamination of the dosimeter; industrial wiping tissue was used to clean the dosimeter before reading. The 200-mr dosimeters were quickly overtaxed as the intensity increased, forcing a shift to the 5-r dosimeter. Experience proved that an operational dosimeter tube would require a number of dosimeters covering the possible range of intensities to be encountered.

Converting the measured intensity to standard intensities by means of an assumed decay curve proved to be an effective way of determining fallout cessation. The fact that the actual decay was somewhat faster than the assumed decay during the first hour (Fig. 3.13) caused a peak in the standard intensity plot at fallout cessation (Fig. 3.3).

4.2 INGRESS OF CONTAMINATED AIR

Results of the aerosol measurements have not been fully evaluated. Nevertheless, the performance of the intake configuration was disappointing. The amount of activity entering the M6 collective protector was virtually the same as that in the outside air; therefore, the system of a plenum chamber and a mushroom intake ventilator offered no significant protection.

There were two known artifacts in the experimental situation that make it difficult to evaluate the results. The first was the blow-in of the wall separating the generator room from the plenum chamber. This caused the generator to draw its cooling air from the entrance tunnel, thus increasing the flow rate of the air in the tunnel.

The second complication was intentionally introduced into the experimental procedure in the form of a flow of 600 cu ft/min in the plenum chamber. This volume is well above the requirement for an operational shelter. (The minimum requirement for a person at rest is approximately 1 cu ft/min. If the shelter capacity is set at 100 persons, the minimum requirement for the shelter ventilation system would be 100 cu ft/min.) However, the 600 cu ft/min actually used should have produced a flow of 30 ft/min in the entrance tunnel. Since the tunnel was 30 ft long and 8 ft high, all particulates having falling rates greater than 8 ft/min should have settled out in the tunnel unless other factors, such as turbulence, were dominating the situation.

The significance of the air-sampling results cannot be evaluated at this time. One of the most important facts to be determined is the range of particle sizes passed by the system. These data can then be compared with the available data on activity-particle size relations for detonations of interest to estimate the potential radiological hazard.

4.3 EFFECTS OF OPENINGS ON SHIELDING

While all the data needed for an evaluation of the radiological characteristics of the shelter are not available, the preliminary data are very promising. The general level of protection in the shelter greatly exceeds the required[1] residual number of 0.001. The center ventilator, which was a mockup of a combination exhaust ventilator and escape hatch, was satisfactory from a radiological point of view. The periscope also was satisfactory. The major source of radiation in the shelter was the entrance. One 90-deg bend in the entrance tunnel appears necessary to reduce this contribution to an acceptable level.

4.4 SUPPORTING TECHNICAL STUDIES

Supporting data have not been reduced at this time; they will be

reported in the final report for the project.

4.5 INITIAL MONITORING FROM SHELTER

The fallout radiation field resulting from shot Diablo was very uniform. Consequently, the single-point measurements in the center of the areas were adequate indicators of the radiological situation in the general region. No significant additional information was provided by the corner measurements or the detailed survey. Since the fallout field was similar to that expected in most of the region contaminated by large-yield nuclear weapons, it would appear that single-point measurements obtained from within shelters or by early monitoring missions provide an adequate basis for decisions with respect to operational recovery.

4.6 STAGING-AREA RECLAMATION

The attempt to achieve a residual number of 0.01 in a cleared area was unsuccessful. However, the soil conditions in the test area were extremely unfavorable. A 3-in. layer of clean fill had to be introduced to establish the conditions for a single pass of the scraping equipment. Since the desired residual number was known to require multiple passes of the equipment, serious difficulties were anticipated for this objective upon the initial laying-out of the areas. This experiment must be rescheduled under other soil and terrain conditions before the range of feasibility can be evaluated.

The operational-dose data gave a residual number of approximately 0.2 for the equipment operators. This is considerably better than the value of 0.5 currently used in planning for operational recovery.[2] There appeared to be little variation in protection afforded by the various types of land reclamation equipment.

4.7 RECLAMATION TEST METHODS

Both methods of predicting the effectiveness of reclamation methods on the basis of use in a small test area performed well in this test. The vertical method gave a good prediction in the 60- by 60-ft and 100- by 100-ft areas. The overestimate of residual number for the 40- by 40- ft area was largely due to spills at the edge of the area where the graders lifted blades. The pass that increased the cleared area to 60 by 60 ft removed this source of radiation. Although both methods gave good estimates, the vertical method appears preferable since less reclamation effort is required to get a result. The over-all test requires less time and therefore exposes the test crew to a smaller dose than the horizontal method.

The results indicate that, for both methods, an accurate prediction can be obtained only if the ratios are based upon the average of many readings around the center of the test area. Plots of ratios based on individual readings are relatively unreliable.

4.8 ALTERNATE BUFFER-ZONE TECHNIQUE

Two tests were made of the barrier technique. Both indicated that a barrier 3 to 4 ft high would effectively reduce the contribution of radiation from outside a reclaimed area to a negligible amount. A rate of about 300 linear feet per equipment-hour was observed. The same length of buffer zone 200 ft wide would require approximately two equipment-hours of plowing. Scraping is even slower. Thus the barrier appears to be about twice as fast as the fastest buffer-zone technique. It would be desirable to determine the effect of barriers of other heights than those tested as well as more detailed measurements of the radiation field over the cleared area inside a barrier in order to develop an optimum procedure. For example, barriers along access routes may need to be quite high to shield vehicle occupants properly.

REFERENCES

1. W. E. Strope, Performance Specifications for a Sound National Shelter System, Report USNRDL-TR-132, Feb. 13, 1957.
2. NavDocks TP-PL-13, Radiological Recovery of Fixed Military Installations, June 1, 1957.

Chapter 5

CONCLUSIONS

The following conclusions are offered on a tentative basis pending complete analysis of the data:

1. The standard Navy ammunition storage magazine (Armco Multiplate structure), buried so as to provide a minimum thickness of 3 ft of earth cover over the crown and provided with all necessary openings for entrances, ventilation, and control purposes, offers a high degree of radiological protection. An average residual number of about 0.0001 was observed.

2. A 2-ft-diameter straight exhaust ventilator that can be designed as an escape hatch is radiologically acceptable.

3. A simple device consisting of a 1-in. pipe projecting through the shelter roof and fitted with a rod carrying a self-reading dosimeter will provide the shelter commander with all necessary radiological information for decision purposes within the shelter.

4. The need for filtration of the shelter air supply has not been resolved.

5. Both the vertical and horizontal methods of predicting reclamation effectiveness give satisfactory predictions in small test areas (less than 100 by 100 ft) under field conditions using land reclamation equipment.

6. An earth barrier 3 to 4 ft high is a satisfactory substitute for a buffer zone and can be created with half the effort required for the fastest buffer-zone method.

7. Single-point monitoring gives adequate radiological information in radiation fields that are relatively uniform.

8. The feasibility of obtaining a residual number of 0.01 in a

cleared area by means of multiple passes with land reclamation equipment has not been established.

Appendix A

DESIGN DETAILS OF RADIOLOGICAL SHELTER AND ASSOCIATED EXPERIMENTAL EQUIPMENT

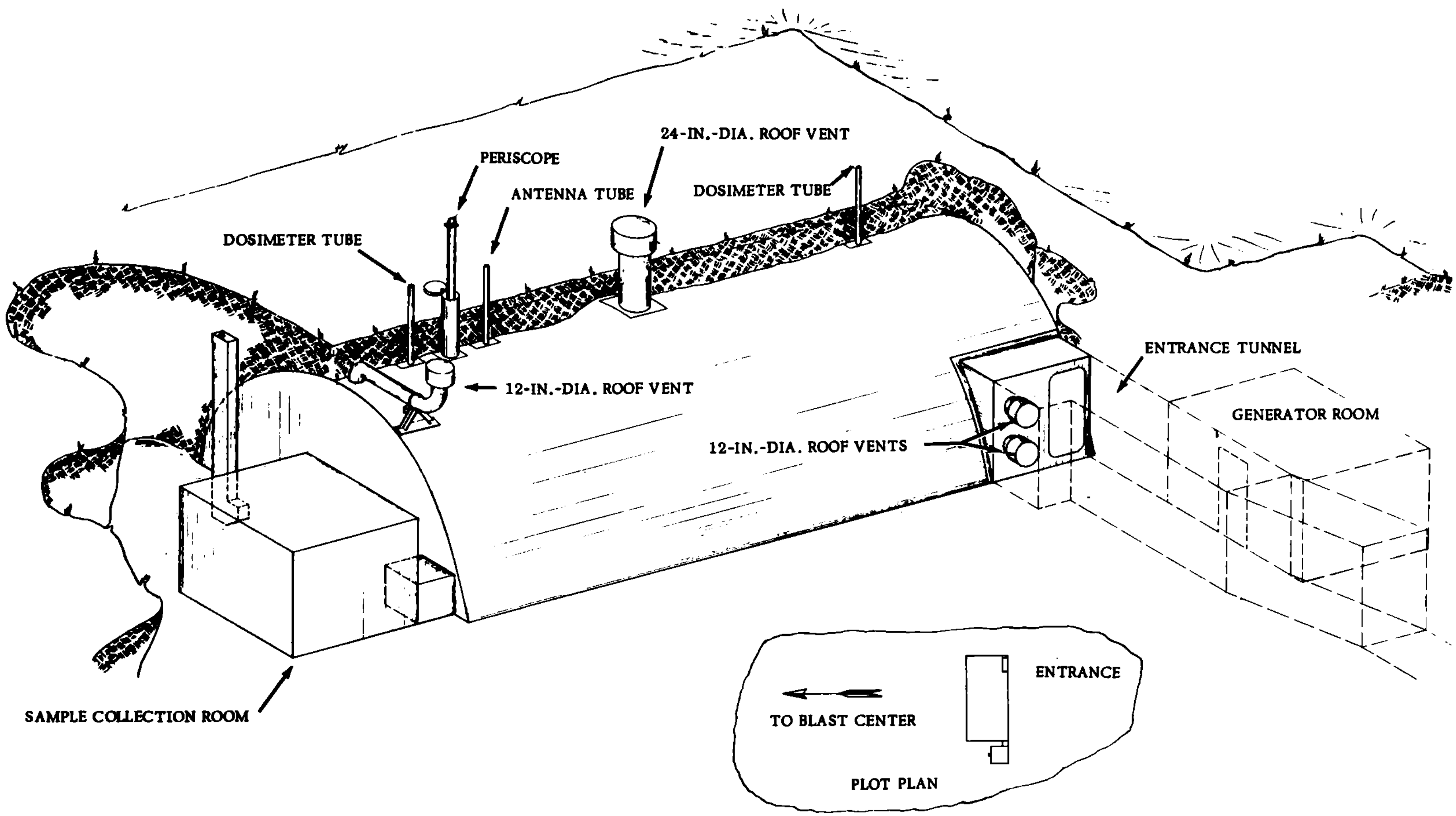


Fig. A.1--Underground Personnel Shelter for Project 32.3.

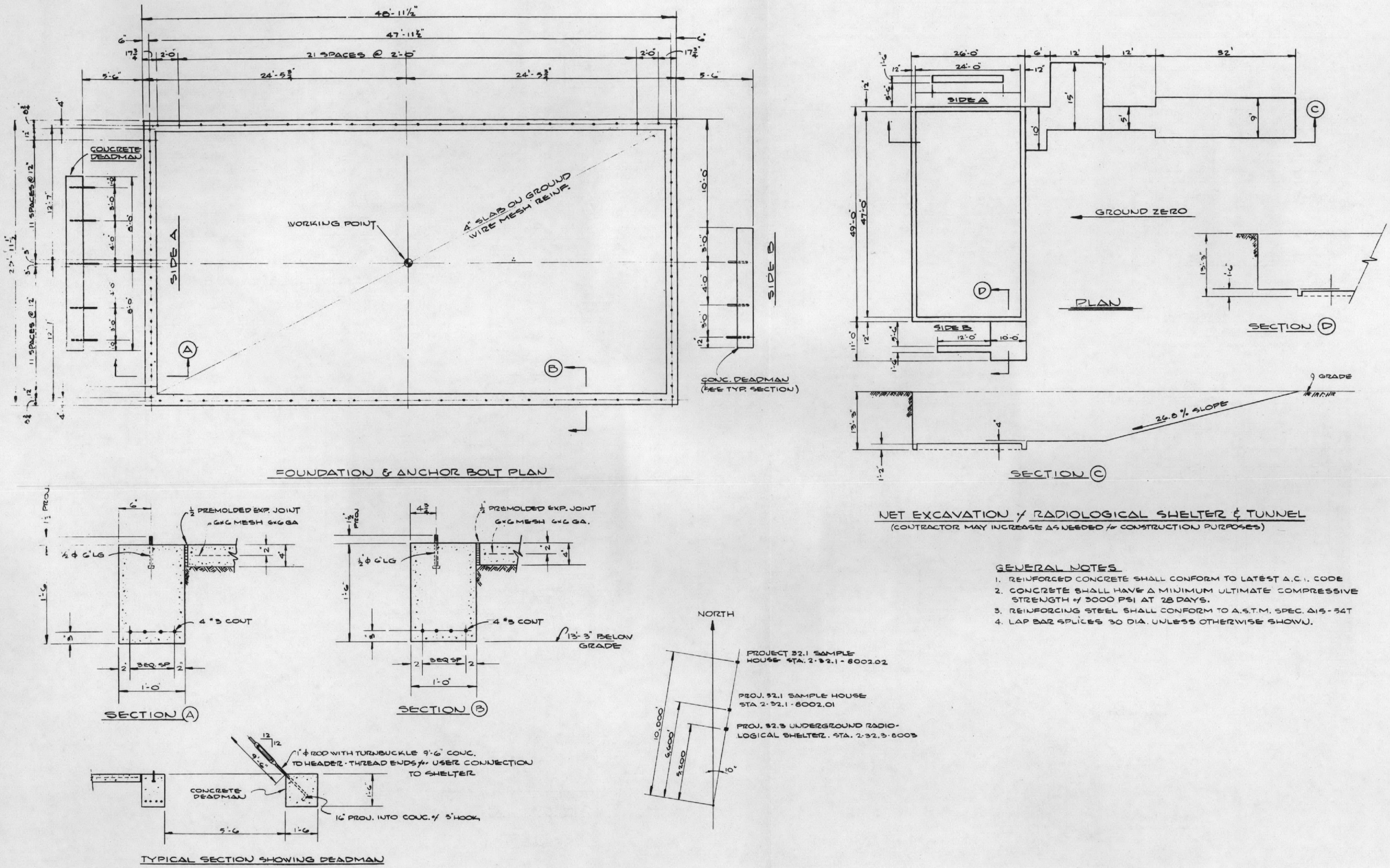


Fig. A.2--Underground Personnel Shelter - Foundation and Floor Slab.

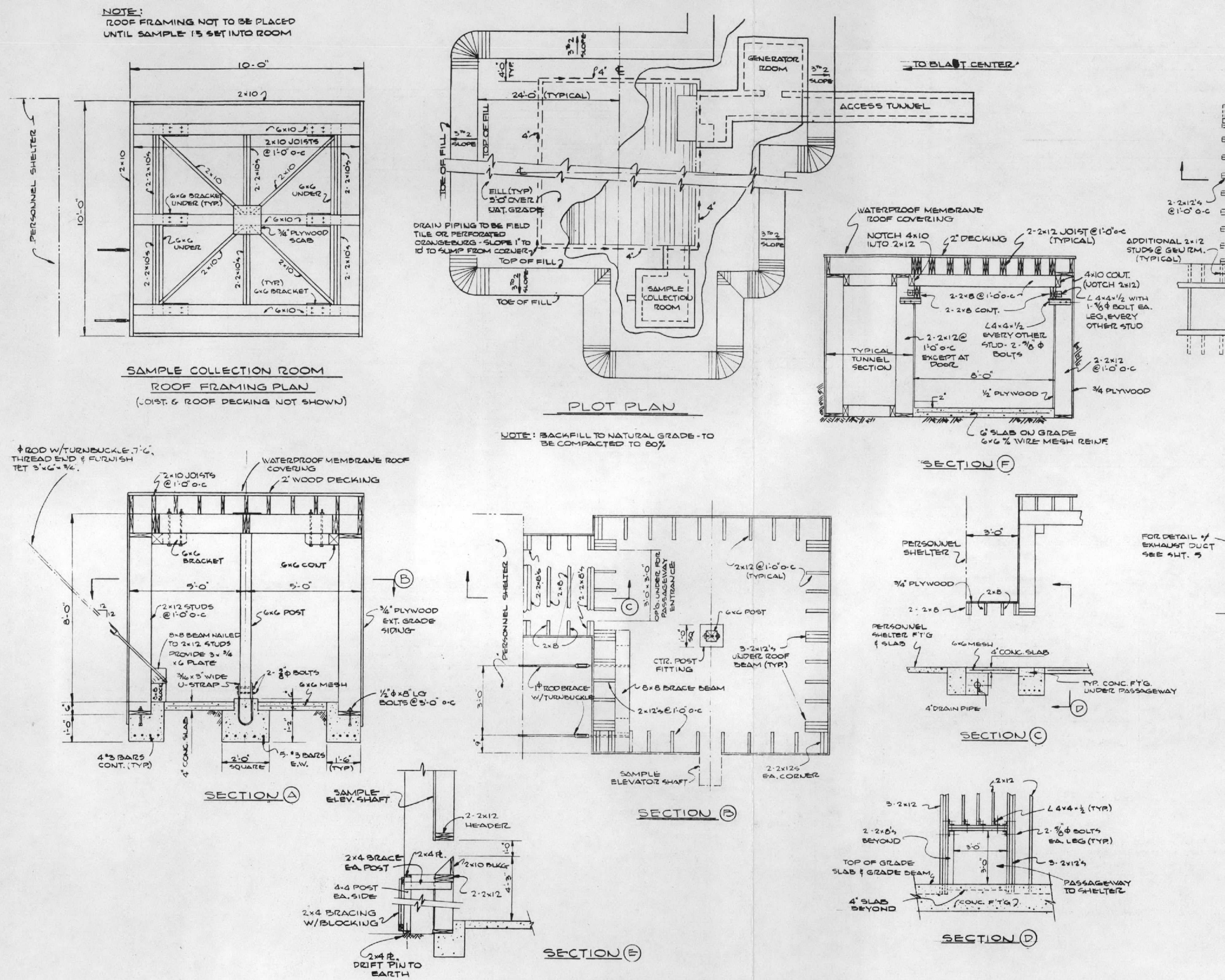


Fig. A.3--Underground Personnel Shelter - Plans, Sections and Details.

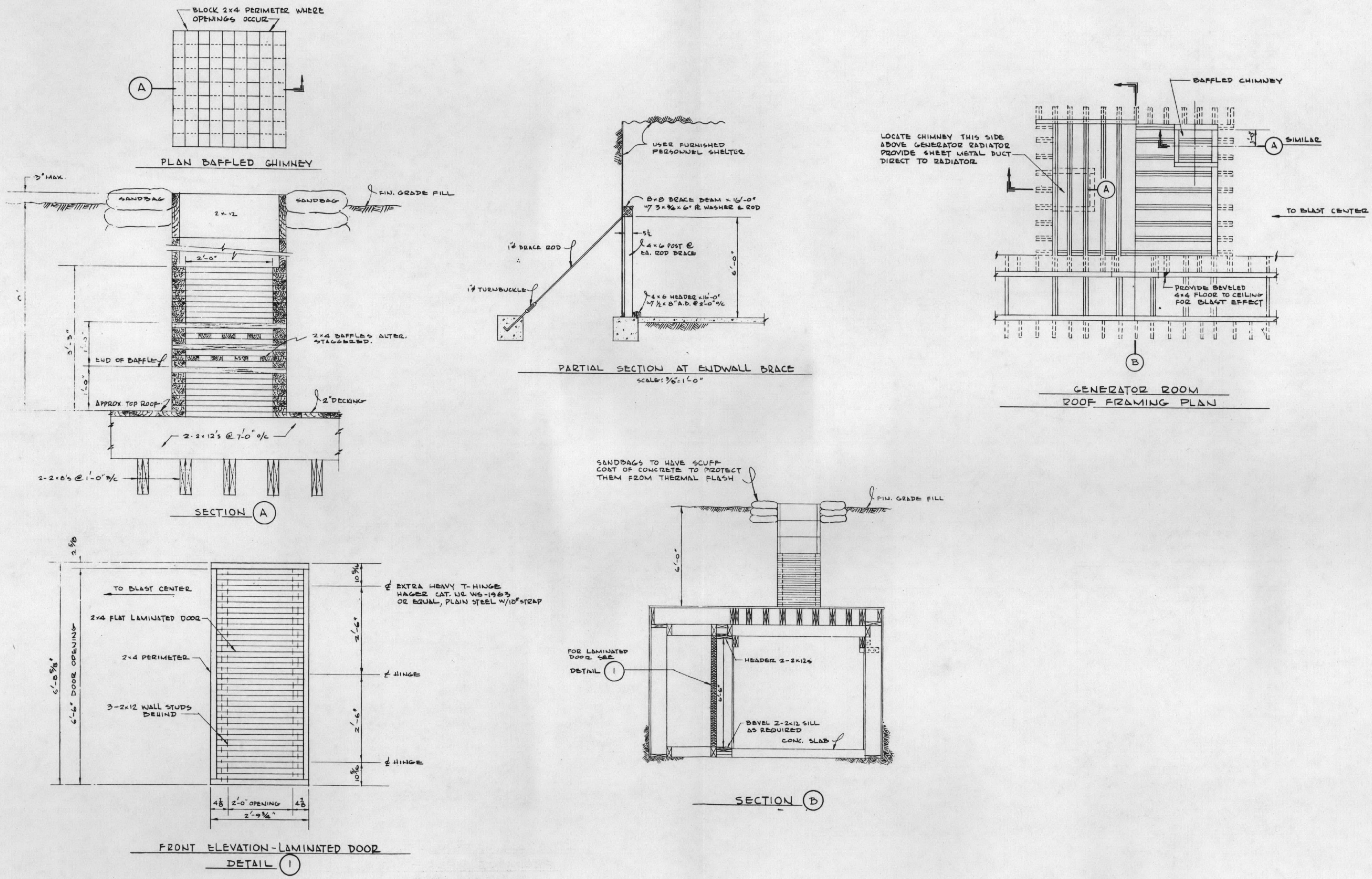


Fig. A.4 --Underground Personnel Shelter - Door and Chimney Plan Section and Details.

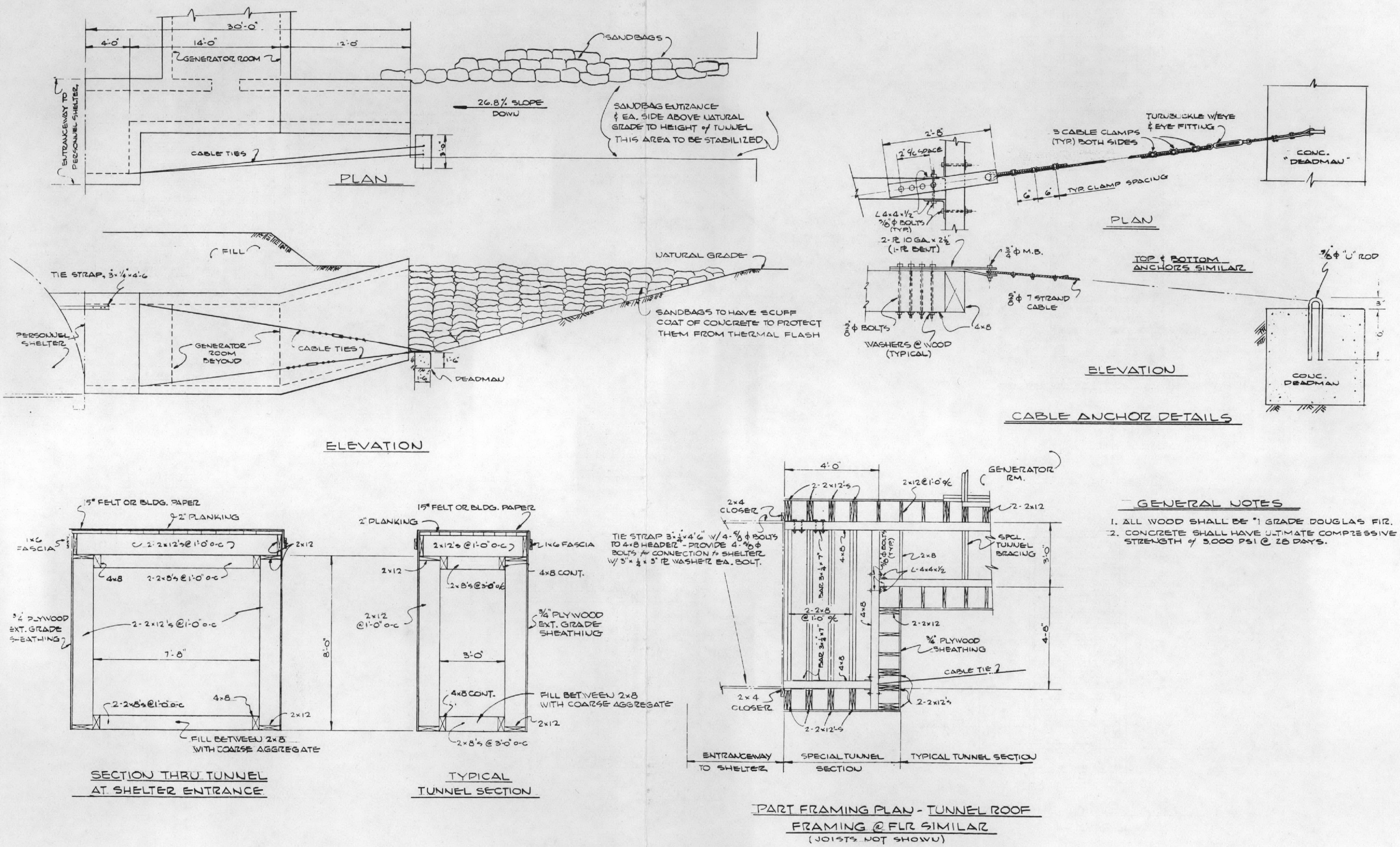


Fig. A.5--Underground Personnel Shelter - Entrance Tunnel Details.

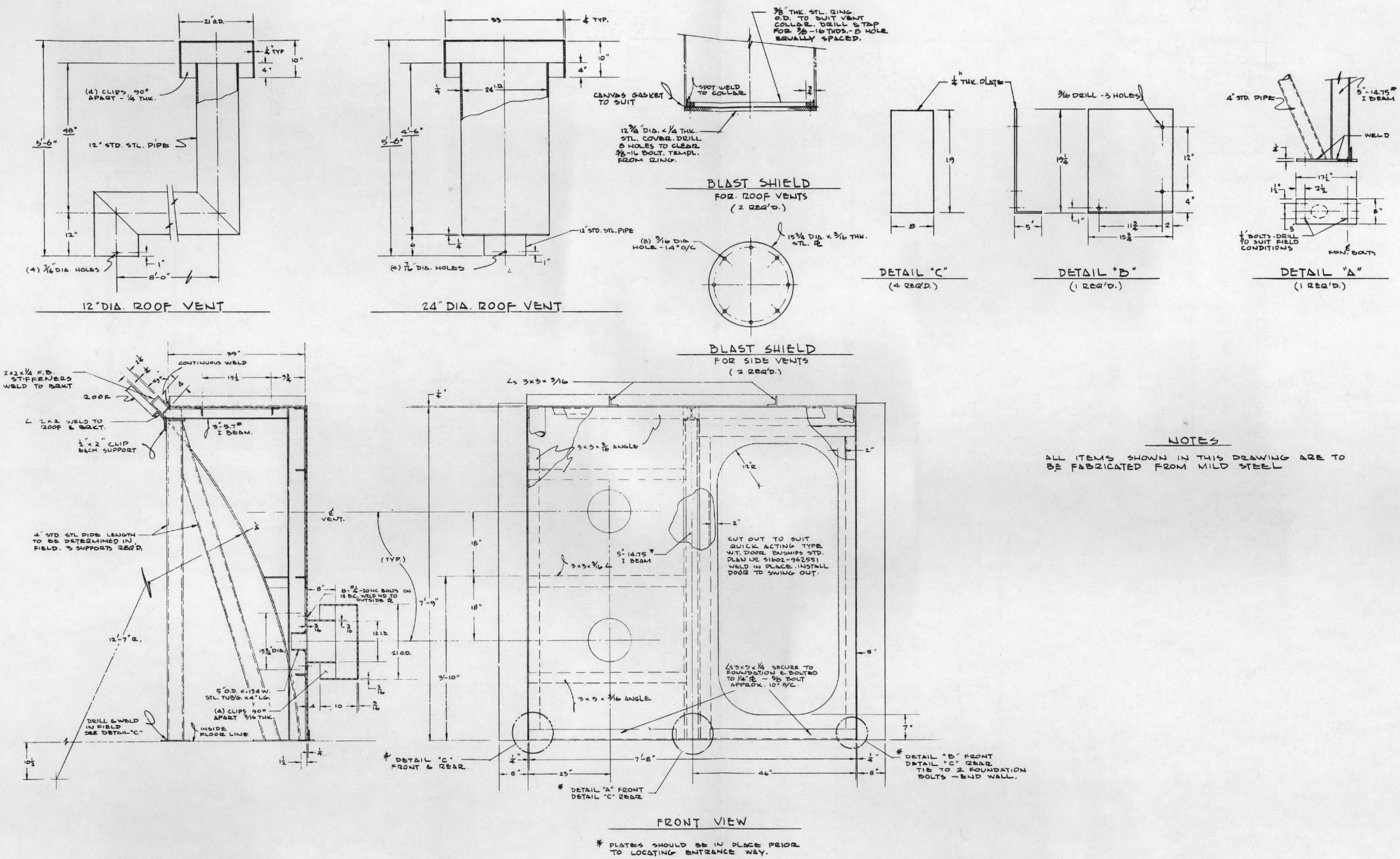


Fig. A.6--Underground Personnel Shelter - Entrance and Vent Details.

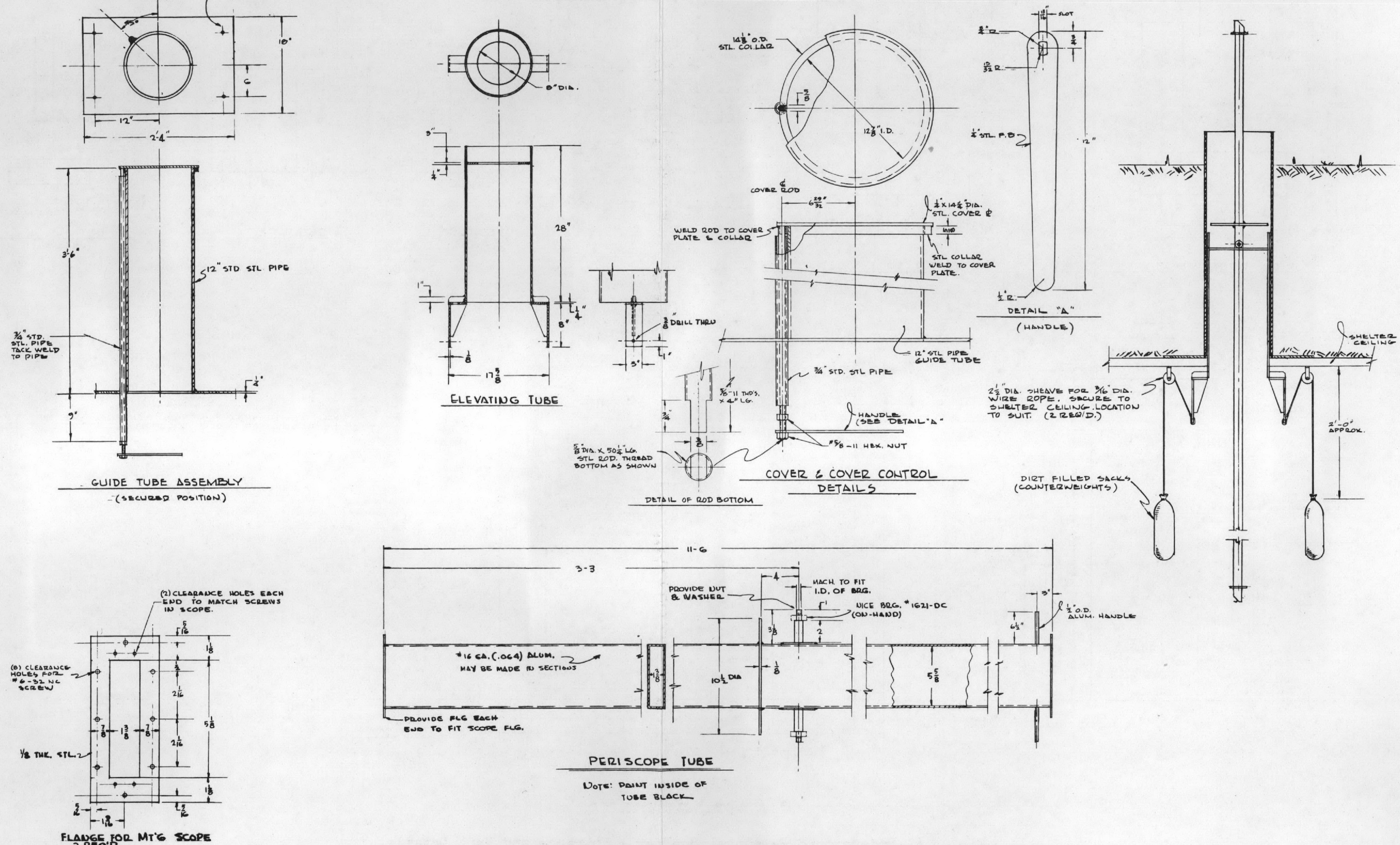


Fig. A.7--Underground Personnel Shelter - Periscope Mounting Details.

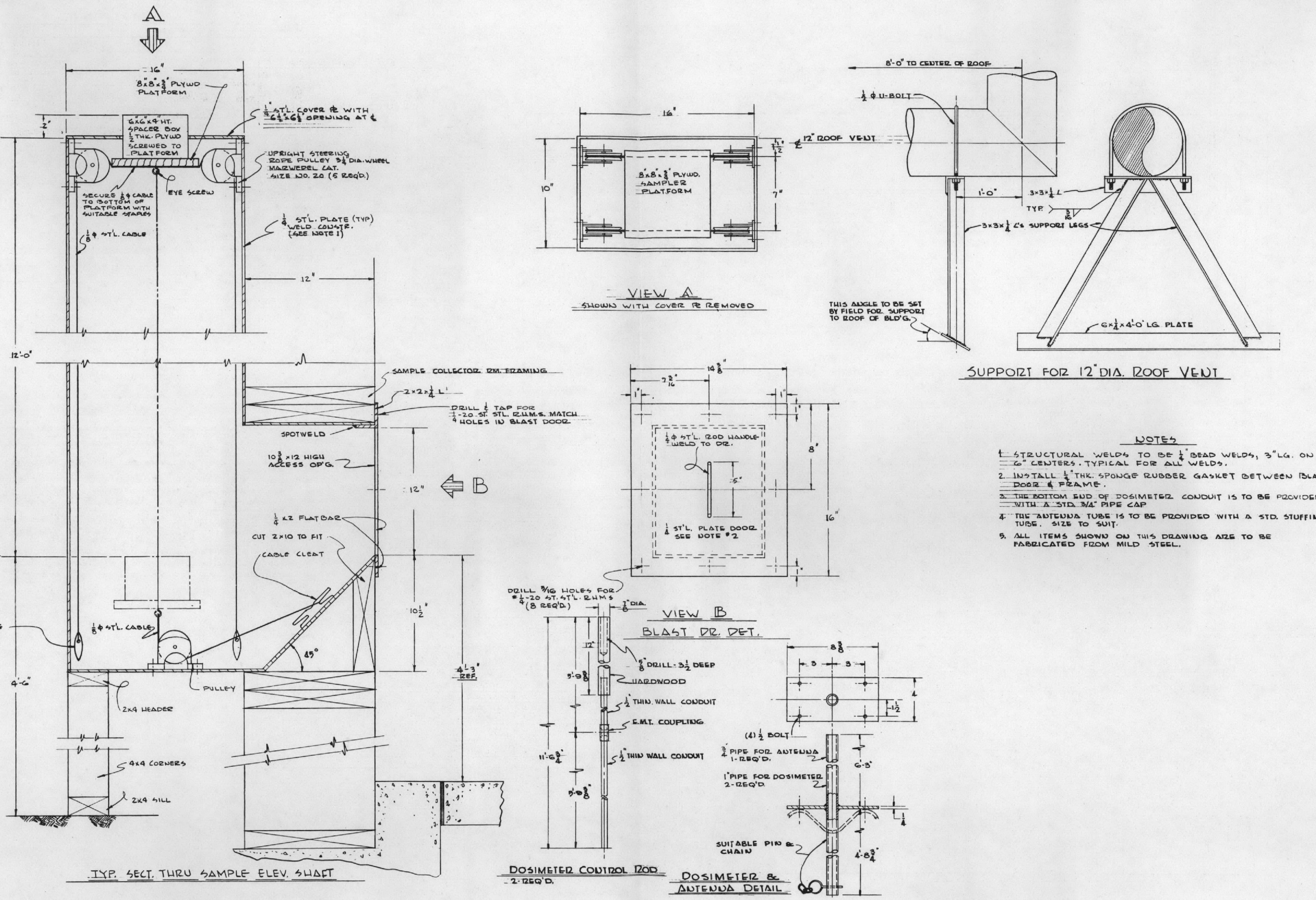
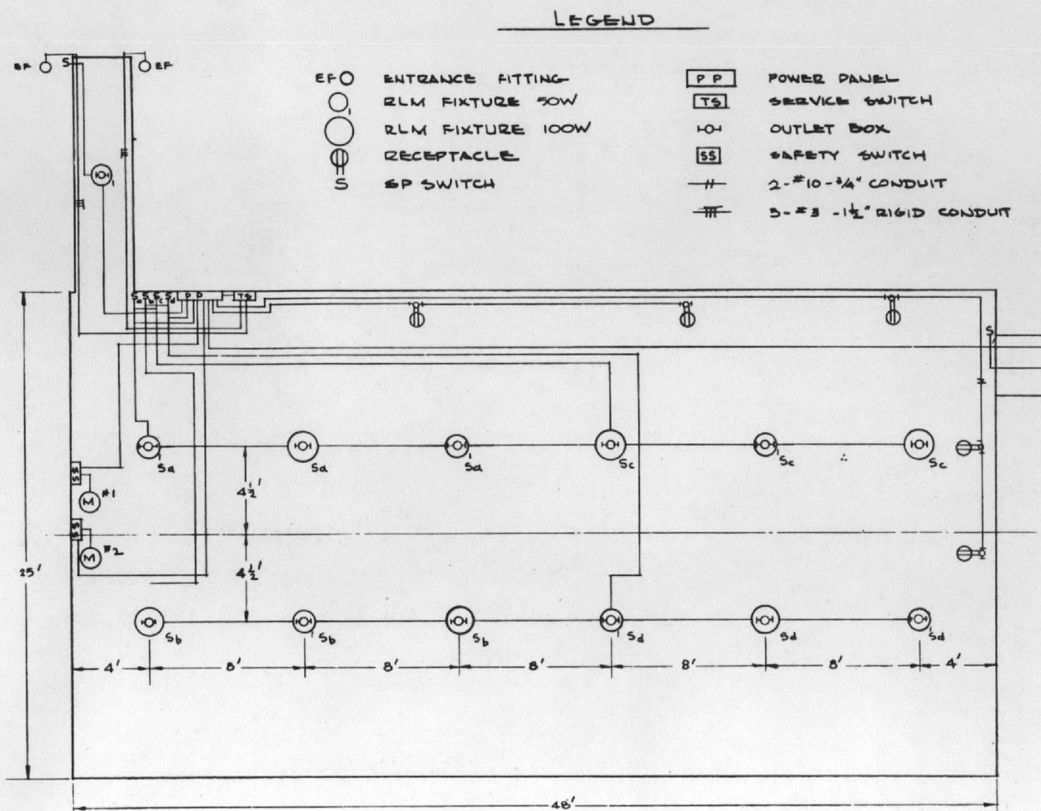
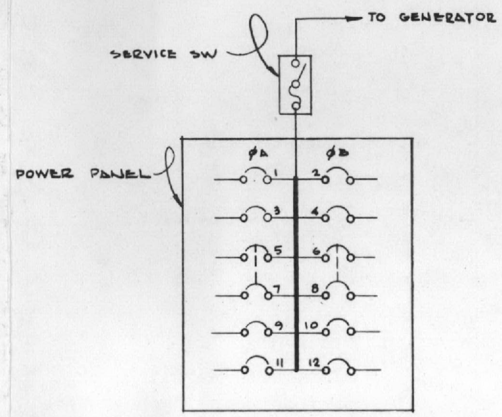


Fig. A.8--Underground Personnel Shelter - Sample Elevator Shaft and Shelter Details.



PLAN VIEW



POWER PANEL SCHEMATIC

LIST OF MATERIAL

QUANTITIES SHOWN ARE FOR ONE SHELTER

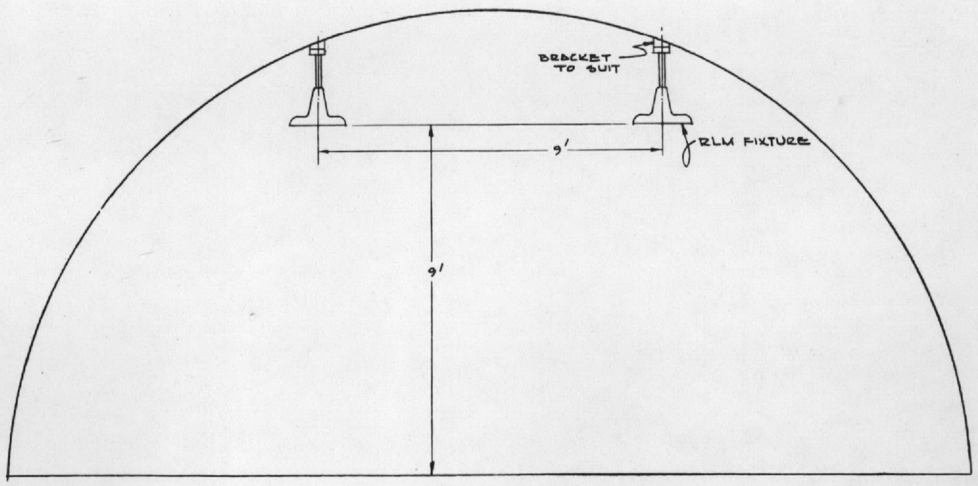
PC. NO.	NAME	NO. REQ.	MAT'L.	MAT'L. SPEC.	STOCK SIZE	REMARKS
	CIR. BRKR. PWR. PANEL 125/250V.	1			SQUARE D #NBR 12-32	3W, 12CKT., 100A MAINS, 5-30A; 7-20A BREAKERS, BOX MH20
	TRANSFER SW., 3PDT 100A FUSIBLE	1			SQARE D #82353F	SHEET METAL ENCLOSURE
	SAFETY SW., 2P-30A-250V, FUSIBLE	2			BULLDOG #SN-321	
	TOGGLE SW., SP-15A-120V	6			HUBBELL #1201	
	DUPLEX RECEPTACLES, 15A-120V	7			HUBBELL #5252	
	RLM STD. DOME FIXTURE	7			WHEELER #HES-100	100W LAMP
	RLM STD. DOME FIXTURE	7			WHEELER #HS-100	50W LAMP
	ENTRANCE FITTING, 1½"-3 HOLES	2			APPLETON #EF-F-150	TYPE FEBS
	OUTLET BOX	AS REQ.				
	TW WIRE, #3 AWG	↓				
	↓ #12 AWG	↓				
	↓ #10 AWG	↓				
	RIGID CONDUIT, 1½"	↓				WITH FITTINGS
	CONDUIT, ½" THIN WALL	↓				↓
	↓ ¾" ↓	↓				↓

NOTES

1. ALL OUTLET BOXES TO WHICH LIGHT FIXTURES ARE ATTACHED MUST BE BOLTED TO THE OUTER SHELL OF SHELTER. THESE BOXES MUST ACCEPT RIGID CONDUIT WHICH WILL BE USED FOR THE LIGHT FIXTURE STEM.
2. THIN WALL CONDUIT WILL BE USED FOR RACEWAYS IN THE INTERIOR OF THE SHELTER.
3. RIGID CONDUIT WILL BE USED FOR SERVICE ENTRANCE.
4. ALL WIRING WILL BE TYPE TW.
5. GENERATOR MUST BE LOCATED TO MINIMIZE ENTRANCE OF EXHAUST GASES INTO THE SHELTER.
6. ALL CONDUIT & SWITCH BOXES SHALL BE BOLTED TO THE SHELTER.
7. ALL ELECTRICAL WORK TO CONFORM TO APPLICABLE SECTIONS OF THE NATIONAL ELECTRICAL CODE
8. PROVIDE DRIVEN GROUND FOR GROUND CONNECTIONS.
9. INSTALL ALL EQUIPMENT 5 FT. ABOVE FLOOR.
10. POWER SUPPLY TO BE 3 WIRE 120/208V.

CIRCUIT BREAKER SCHEDULE

BREAKER NO.	NO. OF POLES	RATING			PHASE
		FRAME	TRIP		
1	1	50 A	20 A	LIGHTS Sa & Sc	A
2	1		20 A	LIGHTS Sb & Sd	B
3	1		20 A	LIGHTS RECEPT. SAMPLE COLL. RM.	A
4	1		30 A	RECEPTACLES - END WALL	B
5 & 7	2		30 A	MOTOR № 1	A-B
6 & 8	2		30 A	MOTOR № 2	B-A
9	1		20 A	ENTRANCE LIGHT	A
10	1		20 A	RECEPTACLES - SIDE WALL	B
11	1		20 A	SPARE	A
12	1		20 A	SPARE	B



ELEVATION

Fig. A.9--Underground Personnel Shelter - Electrical Installation.

Appendix B

INSTRUMENTATION

B.1 INTERIOR SURVEY EQUIPMENT

Gamma-radiation surveys were carried out inside the shelter using seven AN/PDR-27c low-range survey instruments. Since it was possible that the interior intensities might be too low to provide reasonable rate-meter indication, the output of these instruments was connected to a Heiland oscillographic recorder. Each Geiger-Muller tube pulse appears on the recorder trace. Very low radiation levels can be accurately resolved by a pulse-counting technique. In addition, the recorder traces provide a check on the accuracy with which the instruments were read by the operators. Details of the system are given in Fig. B.1.

B.2 FIXED SURVEY-INSTRUMENT SYSTEM

Five low-range survey instruments (AN/PDR-27c) were placed in the shelter at the locations shown in Fig. B.2. The indication on each instrument was recorded, providing a continuous measure of the radiation intensity throughout the shelter. Only one of the five instruments was continuously connected to a Brown recorder. The other four were intermittently connected to a second Brown recorder by a manually operated selector switch. An operator was required to switch the output of the instruments, in sequence, to the second recorder and to periodically adjust the range switches of all instruments. System details are shown in Fig. B.2.

B.3 DIRECTIONAL GAMMA APPARATUS

Instrumentation used to determine directional properties of gamma-radiation fluxes inside and outside consisted of a 1- by 1-in. cylindrical sodium iodide crystal enclosed with an associated photomultiplier tube in an elliptical lead collimator. This assembly was mounted on a

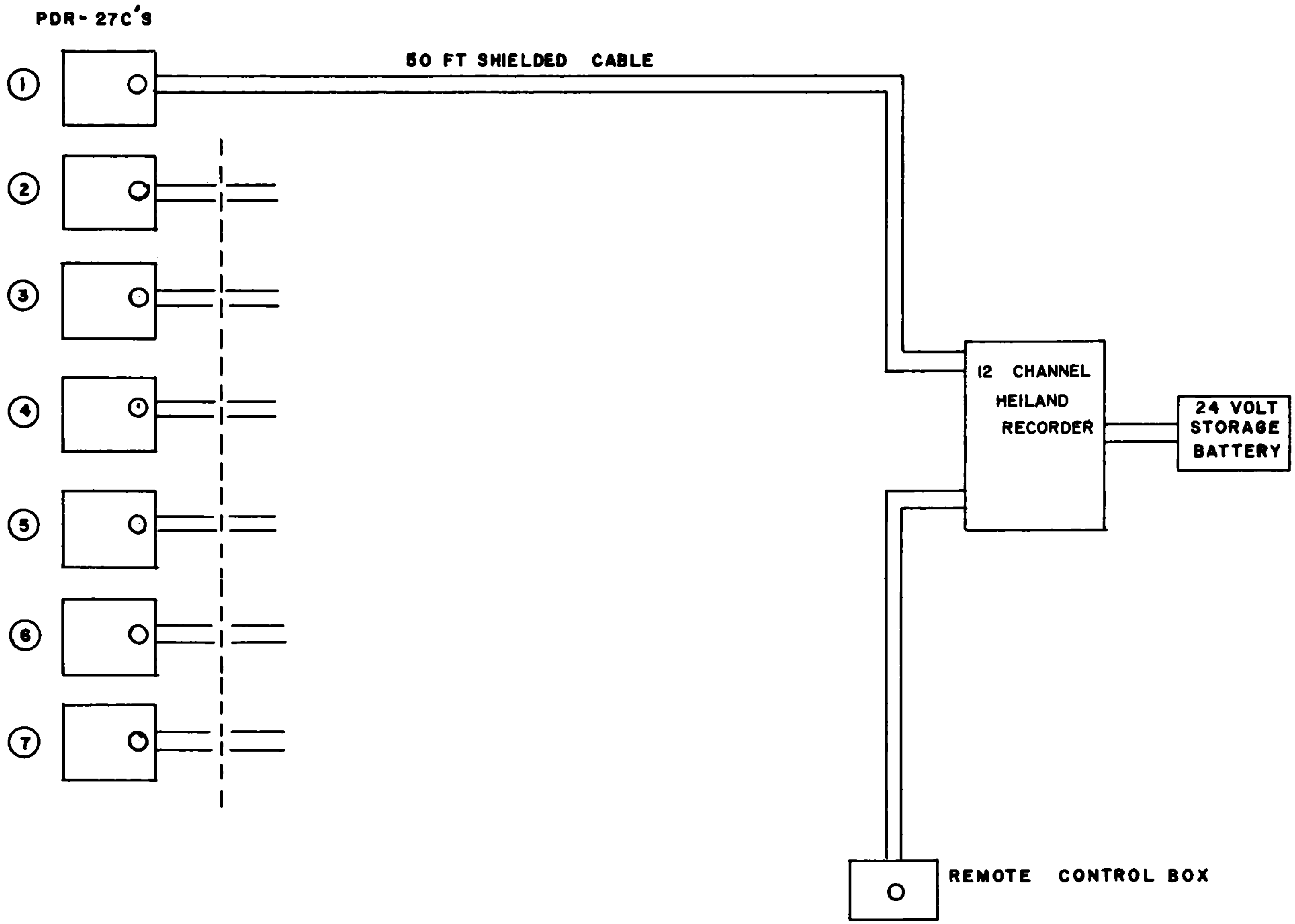


Fig. B.1—Block diagram of recording system for interior survey measurements.

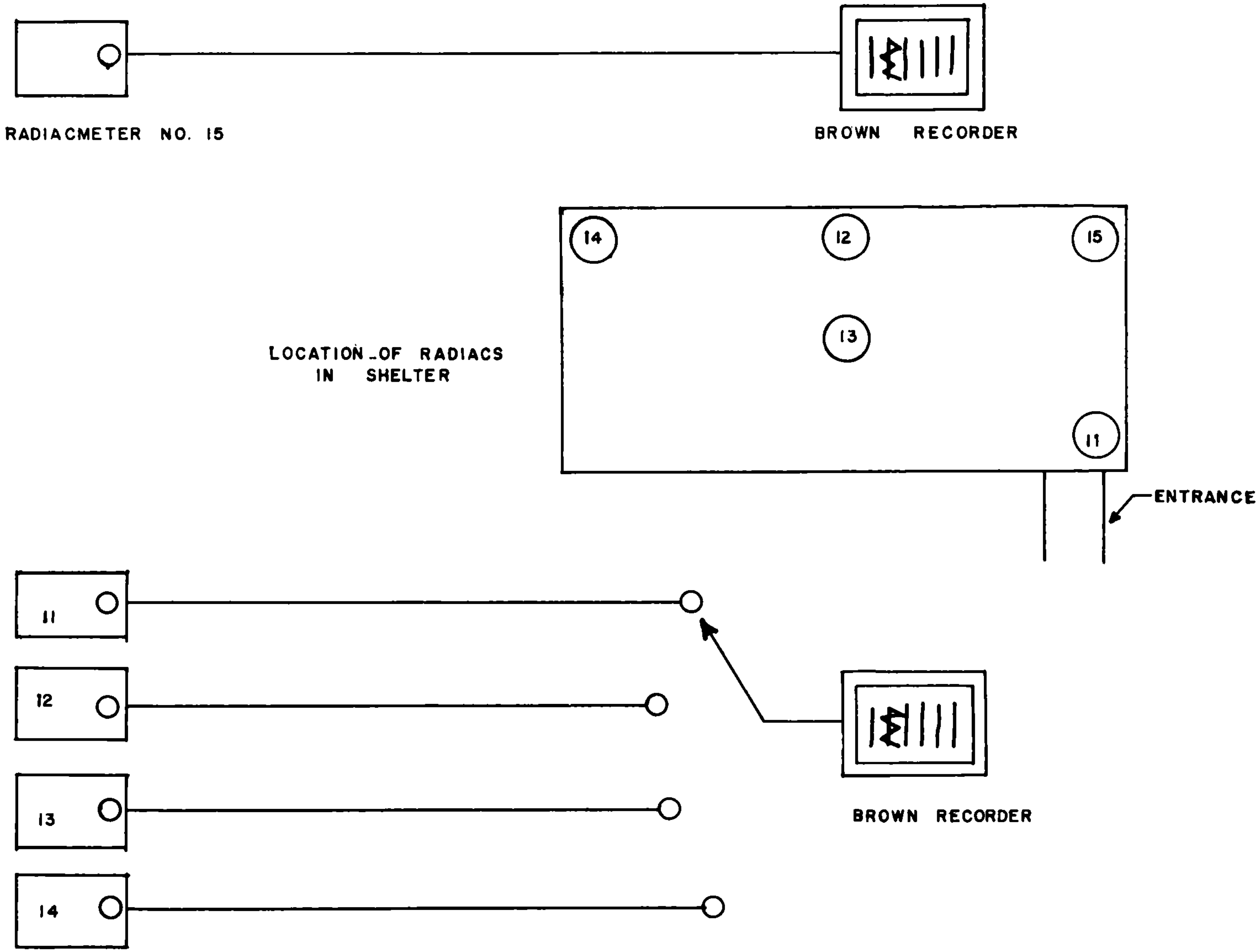


Fig. B.2--Block diagram of system of fixed survey instruments.

rubber-tired metal dolly at a height of 1 meter above the surface. The apparatus was constructed so that the lead collimator could be rotated through a complete circle.

The output of the crystal-photomultiplier combination, in the form of electrical pulses, was used to drive both rate-meter and pulse-counting circuits, as shown in Fig. B.3. The output of the logarithmic rate-meter circuit was recorded on an Esterline-Angus chart during the first 10 min after burst. At later times, when directional measurements were being made, counts were accummulated during 10-sec runs by a Berkeley Digital Scanner, which made a permanent record on printed tape.

The angular resolution of the system, as determined with a radium source, is shown in Fig. B.4.

B.4 SINGLE-CHANNEL PULSE-HEIGHT ANALYZER

Gamma spectra of fallout samples were obtained with an automatic step-scanning single channel analyzer. Samples were prepared as point sources and placed in a 4-in. lead collimator with a 1/2-in. hole. The distance from sample to the detector was maintained at 49 cm. The detector assembly consisted of a 3-in.-diameter solid cylinder of NaI(TI) and photomultiplier (Dumont 6363). This was shielded by an iron-brick cave. The single-channel analyzer was a USNRDL model 1, operated with a 5-volt window through a span of 100 volts. Data were recorded with a Berkeley Digital Scanner and were printed on tape. The equipment is shown in Fig. B.5.

B.5 USNRDL 4-PI ION CHAMBER

The USNRDL 4-pi ionization chamber is a high-pressure argon-gas chamber operated at 600 psig. The ion current is collected on a screen inside the chamber and is measured by use of an electronic electrometer. The current is read on a sensitive ammeter and is recorded through an amplifier by an Esterline-Angus recorder. Fallout particles, which were received in the sample-room collector, were transferred to 1 1/4-in.-diameter Lusteroid test tubes; the ionization current was measured by inserting the test-tube into a cylindrical well extending into the chamber from the top. The sample, when placed at the bottom of the well, is located at the center of the chamber. Decay data can be obtained either by taking measurements from time to time or by leaving the sample in place and recording the ion current on the recorder. The equipment is shown in Fig. B.6.

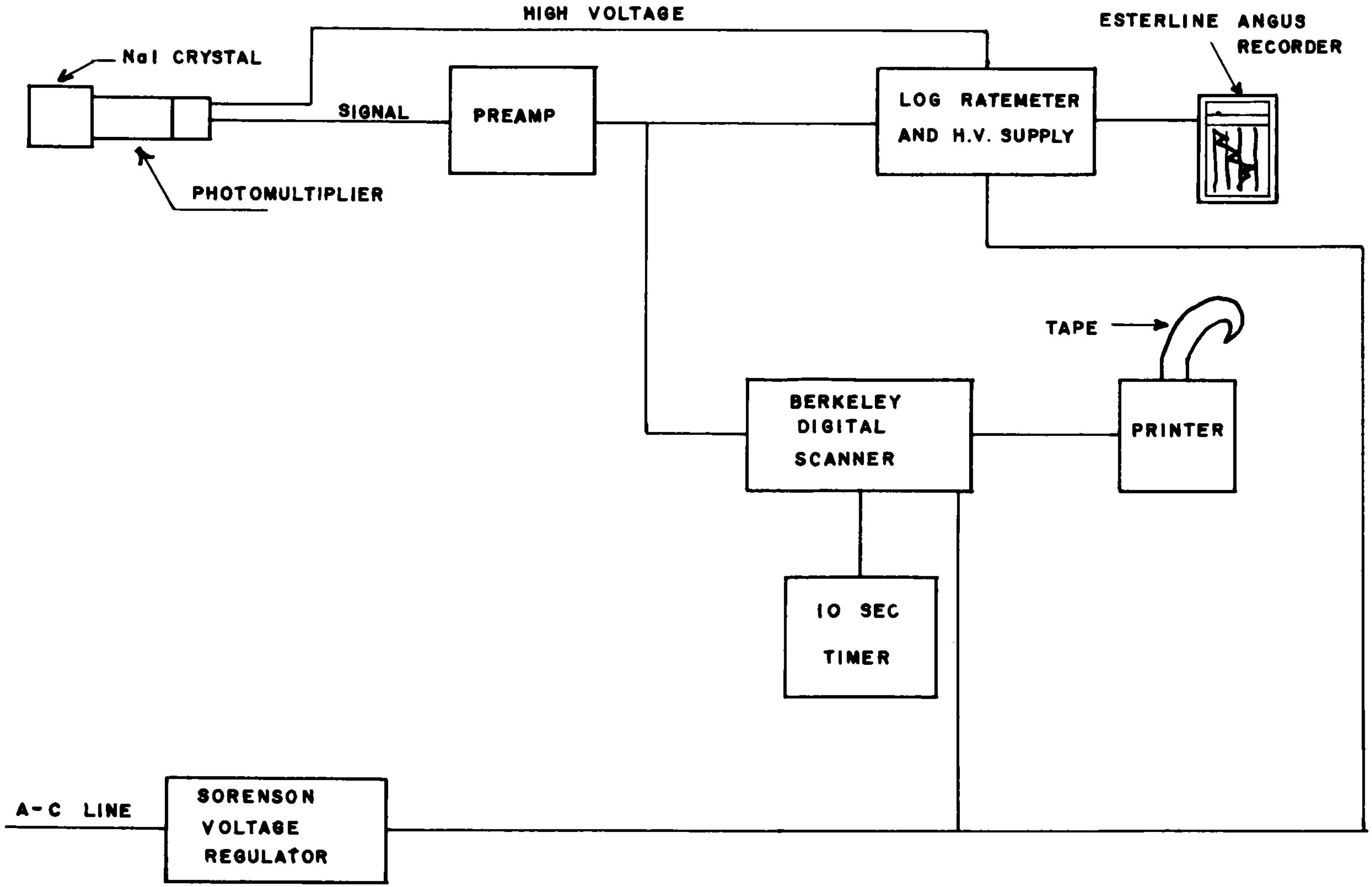


Fig. B.3--Block diagram of directional gamma apparatus.

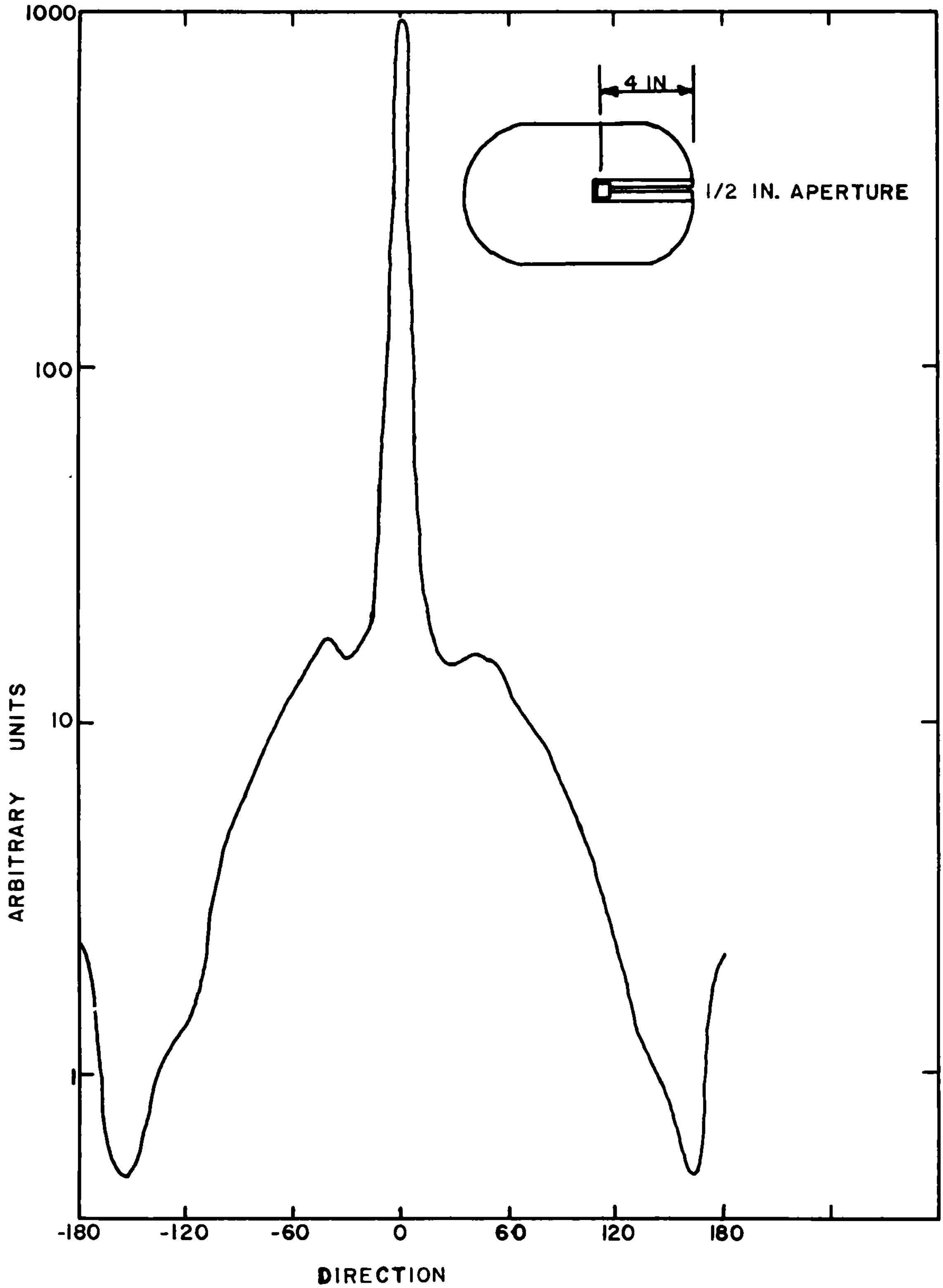


Fig. B.4--Angular resolution of a point source by the directional gamma apparatus.

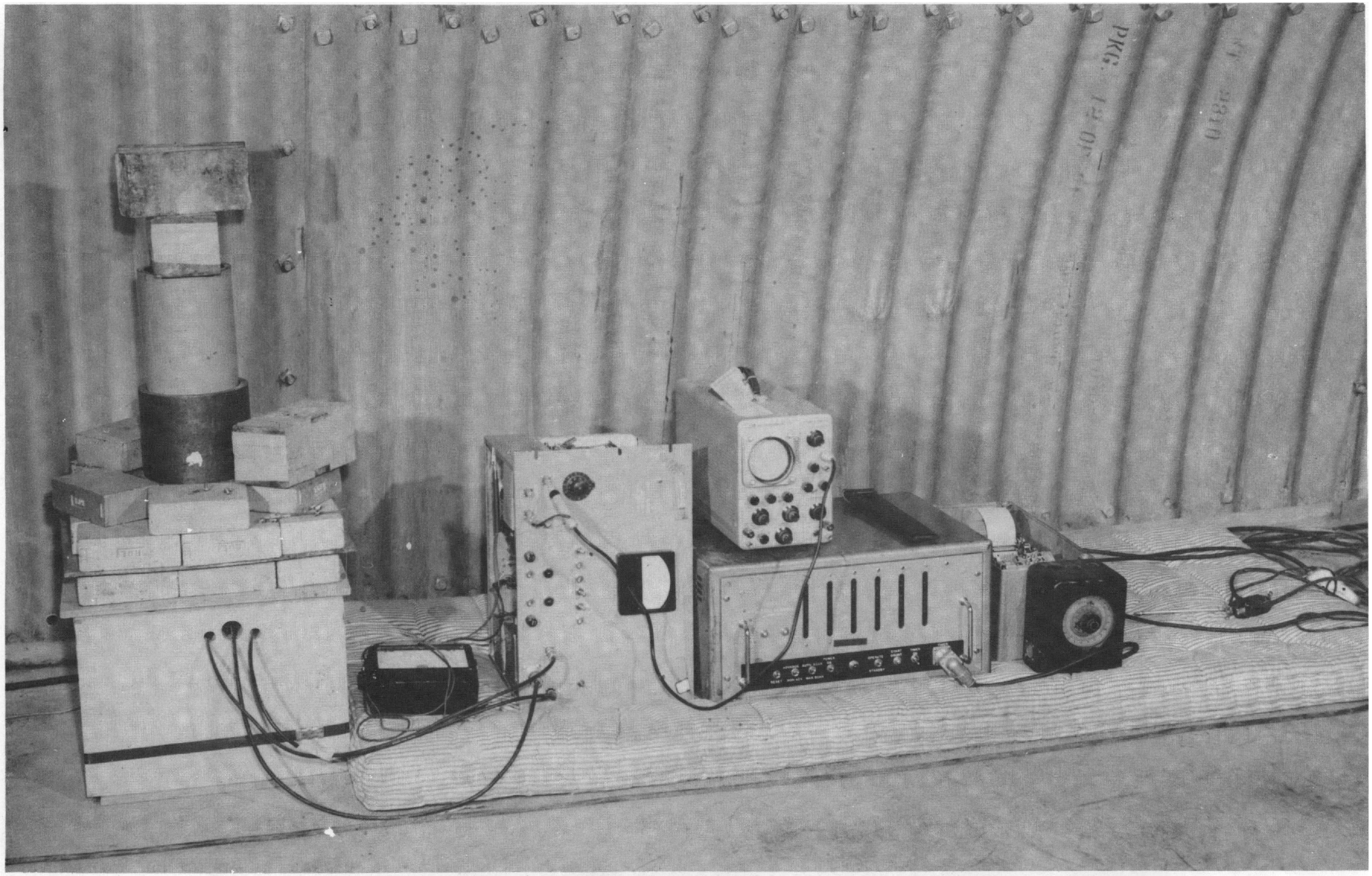


Fig. B.5--View of single-channel, pulse-height analyzer.

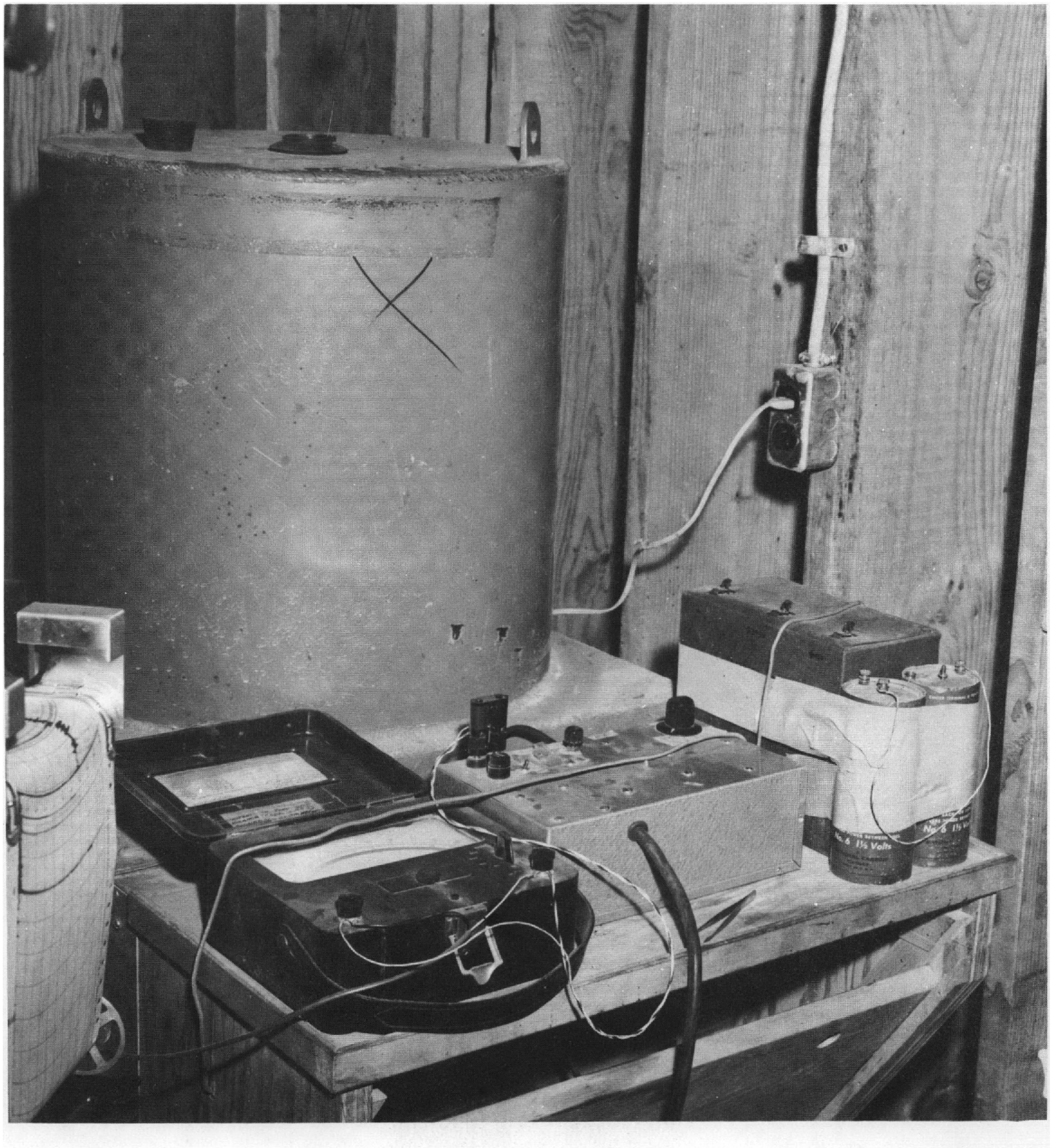


Fig. B.6--View of 4-pi ion chamber in sample-collecting room.

Appendix C

EVENT SCHEDULES

Table C.1--SHOT DIABLO, PROJECT 32.3 EVENT SCHEDULE

Time relative to shot time	Time relative to fallout event	Action	Personnel
D-1 day		1. Gas jeeps and deliver to CP 2. Refuel shelter generator	1. Unruh, Jamison, Thrall, Trolenberg, Phillips 2. Nuckolls
H-8 hr		1. Leave Mercury for CP in carryall and sedan	1. All personnel
H-7 hr		1. Arrive CP area. Dress out at RadSafe.	1. All personnel
H-6 1/2 hr		1. Man jeeps. Clear check station for station 2-32.3-8003	1. All personnel
H-6 hr		1. Arrive at station 2-32.3-8003 2. Start generator 3. Report station manned to CP 4. Communication check. Check radio link to CP. Monitors move by jeep to reclamation area 2 and 3; check portable radio net. 5. Check all instrumentation and shelter equipment. 6. Place jeeps in revetment, cover and tie down 7. Report completion of check to CP	1. All personnel 2. Nuckolls 3. Strope 4. Sword, Unruh, Phillips, Lee, Jamison 5. Miller, Work, Nuckolls, Brown, Laurino Giboney 6. Unruh, Phillips, Jamison, Lee 7. Strope

Table C.1--SHOT DIABLO, PROJECT 32.3 EVENT SCHEDULE (Continued)

Time relative to shot time	Time relative to fallout event	Action	Personnel
H-2 hr		1. Button up entrance. No personnel to leave shelter until called for in event schedule after H-hour. 2. Report status to CP. 3. Start GITR	1. Laurino 2. Strope 3. Miller
H-30 min		1. Stop ventilation, close intake vents. 2. Close exhaust vents 3. House periscope; check dosimeter rods. 4. Charge dosimeters 5. Dress out	1. Brown, Giboney 2. (a) center vent: Laurino, Phillips (b) rear vent: Thrall, Trolenberg 3. Strope 4. Jamison, Lee 5. Unruh, Phillips, Jamison, Lee, Laurino, Brown, Giboney, Work
H-25 min		1. Report completion of shelter closure to CP: request fallout prediction.	1. Strope
H-5 min		1. All personnel assume shot time position: sitting position on centerline at rear of shelter; observe audible count-down.	1. All personnel
H-hour		1. Observe survey meters for initial gamma pulse. 2. Start timing watches 3. Start count up	1. All personnel 2. Strope, Sword 3. Strope

Table C.1--SHOT DIABLO, PROJECT 32.3 EVENT SCHEDULE (Continued)

Time relative to shot time	Time relative to fallout event	Action	Personnel
H+15 sec		1. Check condition of shelter and personnel. 2. Raise ladder, open periscope, then rear vent. 3. Open vent intakes, start one M-6 4. Run up periscope, check condition of superstructure and vehicles 5. Switch count down 6. Man sample room	1. Strope, Miller 2. Trolenberg, LaSpada 3. Brown, Giboney 4. Strope 5. Sword 6. Nuckolls
H+1 min		1. Report shelter condition to CP	1. Strope
H+1 1/2 min		1. Open up center exhaust vent 2. Man Brown recorders	1. Laurino, Phillips 2. LaSpada
H+2 min		1. Run film badges up dosimeters tubes 2. Run film badges up center vent 3. Read all self-reading dosimeters. Charge background dosimeters and place in measurement locations.	1. Thrall, Trolenberg 2. Laurino, Phillips 3. Lee, Unruh
H+3 min		1. Begin I(a) routine on forward dosimeter tube, using 6 min. cycle	1. Thrall
H+4 min		1. Replace dosimeters	1. Lee, Unruh
H+5 min		1. Start second M-6	1. Giboney
H+6 min		1. Start I(a) routine on after dosimeter tube, using 6 min cycle	1. Trolenberg

Table C.1--SHOT DIABLO, PROJECT 32.3 EVENT SCHEDULE (Continued)

Time relative to shot time	Time relative to fallout event	Action	Personnel
Estimated H+6 min	Approach of Fallout	1. Start aerosol sampling. 2. Open fallout collectors; start incremental samplers. 3. Begin directional gamma. 4. Begin absorption measurements.	1. Brown, Giboney 2. Miller, Laurino 3. Work, Jamison 4. Unruh, Phillips
Estimated H+6 to H+10 min	Fallout Arrival	1. Report fallout arrival to CP.	1. Strope
H+15 min		1. Equipment operators, with radsafe monitor, leave CP for equipment location	1. Covey
Estimated H+20 min	Peak Intensity	1. Report peak intensity to CP.	1. Strope
H+20 min		1. Helicopter makes sample pickup and returns to CP.	
H+25 min		1. Prepare for I(c) survey. 2. Terminate directional work. 3. Terminate absorption measurements.	1. Unruh, Phillips, Jamison, Lee, Laurino, Work 2. Work, Jamison 3. Unruh, Phillips
Estimated H+30 min	Fallout Cessation	1. Terminate aerosol sampling. 2. Shut off exterior aerosol samplers. 3. Commence I(c) survey routine. 4. Report fallout cessation time and estimate of standard intensity to CP.	1. Brown, Giboney 2. Miller 3. Laurino, Unruh, Phillips, Jamison, Lee, Brown, Work, Giboney 4. Strope

Table C.1--SHOT DIABLO, PROJECT 32.3 EVENT SCHEDULE (Continued)

Time relative to shot time	Time relative to fallout event	Action	Personnel
H+30 min		1. Equipment operators arrive at equipment; start engines	
H+35 min		1. Make initial Phase II decision based on standard intensity at shelter; request available fallout information from CP if shelter situation unsatisfactory.	1. Strope, Miller, Sword
H+40 min (estimated)	Intensity less than 1 r/hr	1. Advise CP of Phase II situation; request permission to execute.	1. Strope
H+45 min (estimated)		1. Terminate shelter survey. 2. Two 2-man monitor teams man jeeps and execute survey of reclamation areas 2 and 3. 3. Start exterior measurements. 4. Retrieve exterior air samples	2. Unruh, Phillips, Jamison, Lee 3. Laurino, Brown, Giboney, Work 4. Brown, Giboney
H+50 min		1. Receive first key-point measurements from monitors. Select area most suitable or cancel Phase II. Advise equipment crew and CP.	1. Strope, Miller, Sword
H+55 min (estimated)		1. Receive second key point measurements from monitors; make final decision on Phase II; advise equipment crew and CP. 2. Phase II monitors move to selected area.	1. Strope, Miller, Sword 2. Unruh, Phillips, Thrall, Lee, Trolenberg, Giboney

Table C.1--SHOT DIABLO, PROJECT 32.3 EVENT SCHEDULE (Continued)

Time relative to shot time	Time relative to fallout event	Action	Personnel
H+1 hr (estimated)		1. Begin Phase II operations; monitor area and record data. 2. Close fallout trays; terminate incremental sampling. 3. Set up radsafe and dosimeter charge point at shelter entrance. 4. Read all dosimeters.	1. See 2 above plus equipment operators 2. Miller 3. Brown 4. Work, Jamison, Laurino
H+1:10 hrs		1. Grade and scrape 40' by 40' area. Move spoil 500' from area.	
H+1:25 hrs		1. Monitor 40'x40' area.	
H+1:35 hrs		1. Grade and scrape 60' by 60' area.	
H+1:55 hrs		1. Monitor 60'x60' area.	
H+2:05		Grade and scrape 100'x100' area.	
H+2:35		Monitor 100' by 100' area.	
H+2:45		Plow around 100' by 100' area to 500' perimeter.	
H+4:45		Monitor 500' by 500' area	
H+4:45		Grade and scrape 100' by 100' area second time.	
H+5:25		Monitor 100' by 100' area	
H+5:30		Further clearing of 100' by 100' area by front-end loader and dump truck.	

Table C.1--SHOT DIABLO, PROJECT 32.3 EVENT SCHEDULE (Continued)

Time relative to shot time	Time relative to fallout event	Action	Personnel
H+4:45		Final monitoring of area.	
H+5:55		Test completed.	
H+6 hr (estimated)		Close down shelter; man jeeps; return to CP radsafe area. Process through change station; return to Mercury in carryall and sedan	All personnel

Table C.2--SHOT KEPLER, PROJECT 32.3 EVENT SCHEDULE

Time relative to shot time	Time relative to fallout event	Action	Personnel
D-1 day		1. Refuel shelter generator.	1. Nuckolls
H-6 1/2 hr		1. Leave Mercury for CP in carryall and sedan.	1. All personnel
H-6 hr		1. Arrive CP area. Dress out at Rad Safe.	1. All personnel
H-5 1/2 hr		1. Man jeeps. Clear check station for 2-32.3-8003.	1. All personnel
H-5 hr		1. Arrive at station 2-32.3-8003. 2. Start generator. 3. Report station manned to CP. 4. Communication check. Check radio link to CP. 5. Check all instrumentation and shelter equipment. 6. Place jeeps in revetment, cover and tie down. 7. Report completion of check to CP.	1. All personnel 2. Nuckolls 3. Strope 4. Sword, Unruh 5. Miller, Work, Nuckolls, Brown, Laurino, Harris 6. Unruh, Jamison, Lee, Osborne 7. Strope
H-2 hr		1. Button up entrance. No personnel to leave shelter until called for in event schedule after H-Hour. 2. Report status to CP. 3. Start GITR.	1. Laurino 2. Strope 3. Miller

Table C.2--SHOT KEPLER, PROJECT 32.3 EVENT SCHEDULE (Continued)

Time relative to shot time	Time relative to fallout event	Action	Personnel
H-30 min		1. Stop ventilation, close intake vents. 2. Close exhaust vents 3. House periscope; check dosimeter rods. 4. Charge dosimeters.	1. Brown, Harris 2. (a) center vent: Laurino, Osborne (b) rear vent: Thrall, Home 3. Strope 4. Jamison, Lee
H-25 min		1. Report completion of shelter closure to CP: request fallout prediction.	1. Strope
H-5 min		1. All personnel assume shot time position: sitting position on centerline at rear of shelter; observe audible count-down.	1. All personnel
H-Hour		1. Observe survey meters for initial gamma pulse. 2. Start timing watches. 3. Start count up.	1. All personnel 2. Strope, Sword 3. Strope
H+15 sec		1. Check condition of shelter and personnel. 2. Raise ladder, open periscope, then rear vent. 3. Open vent intakes, start one M-6. 4. Run up periscope, check condition of superstructure and vehicles. 5. Switch count down. 6. Man sample room.	1. Strope, Miller 2. Home, Covey 3. Brown, Harris 4. Strope 5. Sword 6. Nuckolls, MacDonald

Table C.2--SHOT KEPLER, PROJECT 32.3 EVENT SCHEDULE (Continued)

Time relative to shot time	Time relative to fallout event	Action	Personnel
H+1 min		1. Report shelter condition to CP.	1. Strope
H+1 1/2 min		1. Open up center exhaust vent.	1. Laurino, Osborne
H+2 min		1. Run film badges up center vent. 2. Read all self-reading dosimeters. Charge background dosimeters and place in measurement locations. 3. Man Brown recorder.	1. Laurino, Osborne 2. Lee, Unruh, Schuert, Anderson 3. Covey
H+3 min		1. Begin I(a) routine on forward dosimeter tube, using 6 min. cycle.	1. Thrall
H+4 min		1. Replace dosimeters.	1. Lee, Unruh, Schuert, Anderson
H+6 min		1. Start I(a) routine on after dosimeter tube, using 6 min. cycle.	1. Home
Estimated H+8 min	Approach of Fallout	1. Start aerosol sampling. 2. Open fallout collectors; start incremental samplers. 3. Begin absorption measurements.	1. Brown, Harris 2. Laurino, Miller 3. Unruh, Osborne
Estimated H+8 to H+10 min	Fallout Arrival	1. Report fallout arrival to CP.	1. Strope
Estimated H+20 min	Peak Intensity	1. Report peak intensity to CP.	1. Strope

Table C.2—SHOT KEPLER, PROJECT 32.3 EVENT SCHEDULE (Continued)

Time relative to shot time	Time relative to fallout event	Action	Personnel
H+25 min		1. Prepare for I(c) survey.	1. Unruh, Osborne, Jamison, Lee, Laurino, Work
		2. Terminate absorption measurements.	2. Unruh, Osborne
Estimated H-30 min	Fallout Cessation	1. Terminate aerosol sampling.	1. Brown, Harris
		2. Shut off exterior aerosol samplers.	2. Miller
		3. Commence I(c) survey routine.	3. Laurino, Unruh, Osborne, Jamison, Lee, Brown, Work, Harris
		4. Report fallout cessation time and estimate of standard intensity to CP.	4. Strope
H+45 min (estimated)		1. Terminate shelter survey.	
		2. Start exterior measurements.	2. Laurino, Brown, Work, Harris
		3. Retrieve exterior air samples.	3. Brown, Harris
H+1 hr (estimated)		1. Start directional gamma measurements on shelter roof.	1. Work, Jamison
		2. Close fallout trays; terminate incremental sampling.	2. Miller
		3. Set up radsafe and dosimeter charge point at shelter entrance.	3. Brown
		4. Read all dosimeters.	4. Work, Jamison, Laurino.